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REPRINT No. 2107

SOUNDING VOYAGE

OF

HER MAJESTY'S SHIP "HYDRA,"

CAPTAIN P. F. SHORTLAND.

1868.

PUBLISHED BY ORDER OF
THE LORDS COMMISSIONERS OF THE ADMIRALTY.

HD27

LONDON:
PRINTED FOR THE HYDROGRAPHIC OFFICE ADMIRALTY;
AND SOLD BY
J. D. POTTER, *Agent for the Admiralty Charts,*
31, POULTRY, AND 11, KING STREET, TOWER HILL.
1869.

Price One Shilling and Sixpence.

23442.

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ERRATA.

At page	8, eight lines from the bottom,	*for* PW	*read* PW_1
,,	18, seven and nine lines from the top	*for* S, S_1, S_2.	*read* $S\ S_1\ S_2$
,,	,, ten lines from the top	*for* Q, Q_1, Q_2	*read* $Q\ Q_1\ Q_2$
,,	20, five and ten lines from the top	*for* S, S_1, S_2.	*read* $S\ S_1\ S_2$,
,,	,, ,, ,, ,,	*for* Q, Q_1, Q_2,	*read* $Q\ Q_1\ Q_2$ and
,,	,, ,, ,, ,,	*for* Q', Q'_1, Q'_2,	*read* $Q\ Q_1\ Q_2$
,,	,, fifteen lines from the top	*for* $Q\ P'\ Q'_1$	*read* $Q\ P_1\ Q'_1$
,,	21, seven lines from the top	*for* $S\ Q_2\ Q'_2$	*read* $S_2\ Q_2\ Q'_2$
,,	,, twenty-three lines from the top	*for* let be	*read* let ρ be
,,	33, third line from the bottom	*for* adr_2	*read* adr^2

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THE HYDRA'S SOUNDING VOYAGE.

1868.

On the 16th September 1867 Her Majesty's Ship *Hydra* under my command, left Malta in consequence of an order by telegraph from their Lordships directing her to proceed to Bombay, touching at Gibraltar to receive my orders and some stores necessary to enable me to execute them; these (*vide* Appendix) we received at Gibraltar by the Peninsular and Oriental Mail Steamer on the evening of the 2nd, and sailed for Bombay at daylight on the 3rd of October following.

Referring to the Stores.—The hawser laid lines called deep sea, medium, and cod respectively, and which we denoted by Nos. 1, 2, and 3 were very well made of the best Italian hemp, and we found them very good, especially No. 2, which proved the most useful; the strength and dimensions of these lines, as well as a description of Brookes' sounding rod, will be found clearly set forth by Staff-Commander Davis in a recent publication to which the reader is referred.

A sounding apparatus, invented by Mr. Griffeth, was lent us for trial and was found to answer well, but as we eventually contrived a machine which I much prefer, and will hereafter describe, I need only refer anyone desirous of information to Mr. Griffeth, of Sheerness.

The common deep-sea lines were but little used, because they were found to break easily.

The copper swivels were not used because the simple mode we adopted of joining the lines by a reef knot with the ends stopped down answered perfectly.

The iron gin blocks were very good and with a small alteration answered very well.

Hodge's accumulators we received on our arrival at Simons Bay. We fitted two circular wooden ends to receive as many accumulators as corresponded in strength to that of No. 1 line in such a manner that they could be removed at pleasure, in order that when using No. 2 or No. 3 line the number of the accumulators might be made proportional to the strength of the line used.

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The extension of the accumulator thus fitted when subjected to different strains was measured, and a scale of strains corresponding to different degrees of extension determined; by this means the amount of the tension of the deep-sea line at any instant was shown by the extension of the accumulator, and we were thus enabled to regulate within safe limits the speed of the engine heaving in the deep-sea line, and in other respects it was found extremely useful. It may here be remarked that the *Hydra* was fitted with a small engine for heaving in the deep-sea line.

During the early part of 1867, whilst obtaining deep soundings off the East coast of Sicily, the *Hydra* was found to lay steadily with her stern to the wind when her jib was hoisted and engines going astern; and it was therefore determined to adopt this position. The after yards were landed at Malta, and therefore it only remained to remove the stern davits and erect a derrick over the stern, where a frame was placed to facilitate the letting-go of the weight.

Let AB in the plane of the paper (Fig. 1) represent the section of the *Hydra*'s poop deck by a vertical plane passing through the derrick AC; D a large single block lashed to the head of the derrick; *b*, the chock of the letting-go frame; EF the accumulator with its end E secured to the heel of the derrick; FDG the accumulator pendant hooked to the accumulator at F, rove through the block D, with the gin block G hooked to its other extremity; IGH the deep-sea line rove through G.

It will easily be perceived that as the tension of the line IGH increases, the strain on the pendant FDG increases; and the accumulator EF extends in direction of the pendant FD, by a distance proportional to the magnitude of the increase.

When the angle IGH is a right angle the strain on the deep-sea line is about $\frac{7}{10}$ that on the accumulator pendant, and when the angle IGH is 120° the strains are equal.

One end of a measuring tape was secured to the rim of the wooden end F of the accumulator; the other end, after reeving through a small roller secured in the rim of the other wooden end E, had a small weight attached to it; so that as the accumulator extended or contracted the tape was kept tight. The reading of tape with the accumulator in its normal position was taken; the reading in any other position of the accumulator gave its extension and the corresponding strain on the pendant.

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In practice the angle IGH was generally between 120° and 90°, and thus the strain on the sounding line was estimated sufficiently near for practical purposes.

The letting-go frame, of which Fig. 2 is a vertical section.—AB is the intersection of the poop deck of the *Hydra* by a vertical plane; AC the letting-go frame; B*b* a wooden chock with a hinge at *b*, round which A*b*C is capable of turning in the vertical plane into any other position A′ *b*′ C′ shown by the dotted lines. At A there is a small bolt in the deck which passes through an aperture in the inner end of the frame; a pin or forelock passes through a hole in the end of this bolt, which, when inserted, secures the end A of the frame to the deck and prevents its tilting, and when withdrawn allows the end A to be raised. EDC Brookes', or any other sounding apparatus of which the tube passes through an aperture in the weight DC; FE the sounding line.

In Fig. 3, ABC is a horizontal section of the frame; A the aperture through which the bolt passes which carries the pin or forelock that prevents the frame tilting; BC the groove which admits the lower end of the tube and allows it to be pushed with the weight in the direction BC, towards the outer end of the frame.

When using the frame the weight was placed at B, so that the hole in the weight might coincide with the inner end of the groove at B; here the tube was inserted and the weight attached to it; the deep-sea line hauled taut and the weight pushed out towards C; the sounding reel was then hove back so that the line might be sufficiently taut to support the weight without raising it from the frame; the brake was then applied to the reel and all was ready for letting-go.

When the proper opportunity arrived the pin or forelock at A was withdrawn, the inner end of the frame raised, and when the outer end of the frame was clear of the weight, the brake was released and the weight descended into the ocean.

The sounding line was wound tightly and evenly round a large strong reel, the revolution of which was commanded by a brake.

The apparatus used eventually for bringing up from the bottom of the ocean the water and soil consisted of three parts:—

1. A tube ABCD (Fig. 4), made in three parts which screwed together at B and C, with conical valves at A B and C respectively opening upwards or in the direction CA, and a butterfly valve opening in the same direction at D near its lower extremity. The lower end of the tube at D was chamferred to

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enable the tube to penetrate the bottom easily. This part was taken from a tube that had, I believe, been used by Captain Spratt for a similar purpose.

2. Consists of a tube EA (Fig. 5), which screws on to the former at A; P is a piston capable of moving freely along the tube EA carrying a rod PEF on which is a disengaging spring. In the piston there is a small hole which allows the water to pass through it in limited quantities; at *h* there are two holes in the tube of equal dimensions, one on each side, so situated as to be below the piston when it is at the upper end of the tube in its position for letting-go, and of sufficient size to allow rather more water to pass through them than can pass through the conical valves.

3. The disengaging spring, which was invented by Gibbs, the blacksmith, of the *Hydra*, consists of a rod GFH (Fig. 6), with a hook F nearly perpendicular to its length, but slightly inclined upwards. G*f*H is a steel spring bent in a bow with its ends secured at G and H; a slit is cut in the spring at *f* through which the hook F*f* passes when the spring is pressed back towards the rod in direction *f*F. When the spring is pressed back, as in (Fig. 7), a link *k* to which the weight is suspended is placed over the hook; when the pressure on the spring is released the spring acts against the link and will throw it off the hook unless a sufficient weight is hung on the link. It is easily perceived that by adjusting the strength of the spring it may be regulated to throw the link off with any required weight attached to it.

When prepared for use the parts are screwed together as in (Fig. 8). The tube EABCD placed vertically through the hole in the centre of the weight W*w*; the piston P drawn to its full extent; the link *k*, through which the hanging wire or line L*kl* has been passed, is then hung to the hook F*f* the spring being pressed back against the rod for the purpose. The sounding line is then hauled taut to take the weight, and the resulting force on the link *k* acts to keep the spring back against the rod; the length of the hanging wire or line having been previously so adjusted that, when the tube was placed vertically with its bottom D resting on the deck and the piston P in its lowest position, the weight *w*W also rested on the deck with the hanging line L*kl* slack, so that the spring G*f*H threw the link *k* off the hook.

To describe the action, suppose the tube with the weight suspended as above and the whole hanging by the sounding line. When the line is allowed to run the whole will descend vertically

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in the water; the butterfly and conical valves will open and allow the water to pass up through the tube and out of the holes *h*, *h*, under the piston P; when the bottom of the tube strikes the bottom of the sea the weight carrying the piston continues to descend; when the piston P has passed the holes *h*, *h*, the water contained in the tube between P and A can only escape through the small hole left in the piston for that purpose, its pressure in consequence becomes greatly increased, and, acting vertically on the valve A, not only shuts it but presses the tube into the bottom with considerable force until the piston has descended sufficiently to allow the weight W*w* to touch the bottom; when the hanging line L*kl* slacking allows the spring to throw the link *k* off the hook, and thus the weight becomes disengaged from the tube. The sounding line being now hauled in pulls the tube through the hole in the weight; the valves close and retain the bottom water and soil in the tube.

Sounding Lines.—If a line hanging vertical in the sea be cut by a horizontal plane the section of its surface will be a curve differing slightly from a circle. The pressure of the sea on all points of this horizontal curve will be equal, and therefore, the effect of the friction between the line and the water upon an element of the line moving vertically through the horizontal plane, will be proportional to the length of the above curve, whilst the strength of the line is proportional to the area of the same curve; and, since this relation evidently holds for all points of the line, it holds for the whole line immersed in the sea. Therefore if F be the amount of friction on a given line passing through the sea in direction of its length with a given velocity, S the strength of the line, and *c* the length of its curved boundary formed as above, we have the following relation—F : S :: *c* : c^2 or F : S :: 1 : *c*; hence the larger the line the greater will be its strength in proportion to the effect of friction on it.

The practical conclusion to be drawn from this truth is, if a line of given size be just capable of performing a given sounding duty, a larger line, other circumstances being the same, will be able to perform a larger duty with an equal liability to break, or the same duty with a less liability to break. By a similar process of reasoning the same may be shown to hold good when sounding in a current.

If part of a deep-sea line be immersed in the sea so that it may hang vertically and the other part be wound on a reel capable of revolving freely, the specific gravity of the line being greater than

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that of water it will descend, slowly dragging the other part of the line after it. If a weight be attached to the lower extremity of the line the velocity with which the line will descend will be increased, and upon the weight striking and resting upon the bottom the velocity of the line will gradually diminish until, after a short interval, it will be reduced to a velocity differing insensibly from that due to the weight of the line alone. The degree of precision with which the instant of the weight striking the bottom can be determined depends evidently on the relation which these two velocities bear to each other, and their ratio may be taken to estimate it; that is to say, if V be the velocity with which the line is descending just before the weight strikes the bottom, and v be the velocity due to the weight of the line alone at the depth under consideration; then $\frac{V}{v}$ may be taken as a measure of the precision with which the instant of the weight striking the bottom can be determined with the line running freely off the reel.

Suppose now a force be applied to the line tending to diminish the velocity of its descent by a quantity v'; then the accuracy with which the instant of striking can be determined in this case will be proportional to $\frac{V-v'}{v-v'}$. Since V, v, and v' are always positive quantities if v' never exceeds v, and by the nature of the case V is always greater than v, $\frac{V-v'}{v-v'}$ will be always greater than $\frac{V}{v}$; or, the precision with which the instant of striking can be determined, other circumstances being the same, will be greater when the descent of the line is resisted by a small force, and will be greatest when $v'=v$, or when the resisting force is equal to the weight of the line in the water. From this follows the practical conclusion that a sounding line should not be permitted to run free, but should be resisted by a force, and that the amount of force calculated to produce the best result is that which is equal to the weight in water of a length of the line equal to the depth to be determined.

Let P (Fig. 9) be a pulley at rest; PW a sounding line passing over it and descending vertically under the action of a weight W the line being kept at a given tension; suppose also that in a unit of time W_1, dragging the line after it, descends to W_2. If now we suppose P to have a horizontal motion in direction Pp_1p_2, such that when the weight starting from P arrives at W_1 P will arrive at p_1, and that when the weight arrives at W_2 the pulley will arrive at p_2; also let p_1W_1 and p_2mW_2 represent

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the line in each of these positions respectively, and draw p_1m perpendicular to p_2mW_2.

If we suppose the pulley to stop at p_1 the length of the line at the given tension that will pass over the pulley in a unit of time after will equal the vertical distance between W_1 and W_2, but with the pulley in motion the length of line that will pass over the pulley in the same interval will equal $p_2mW_2 - p_1W_1 = p_2m +$ vertical distance between W_1 and W_2; therefore the length of line that will run over the pulley in motion in a unit of time exceeds that which would have run over it at rest in the same time by p_2m very nearly, and therefore the interval of time required for a given short length of the line W_1W_2, to pass over the pulley in motion is less than that required to pass over it when at rest by $\frac{p_2m}{W_1W_2}$ very approximately. Now $p_2m = p_2p_1 \cos . p_1p_2m$ and therefore the alteration in the interval of time in question due to the motion of the pulley may be taken equal to $\frac{p_1p_2}{W_1W_2} \cos\ p_1p_2m$, the interval being diminished when the pulley moves from the weight and increased when it moves towards it.

An example may perhaps make this clearer.

Let P move at the rate of 100 feet in a minute, or about one mile an hour; the interval at which two consecutive 100-fathom marks would have passed the pulley at rest, other circumstances being the same, to be $1^m\ 40^s$ or 360 feet per minute, and the inclination of the sounding line to the vertical to be 30°. Then, if the vessel be moving from the weight the diminution of the interval due to the vessel's motion will be $\frac{100}{360} \cos\ 60° \times 100^s$, or very nearly 14^s; or the interval, instead of being $1^m\ 40^s$, will be reduced to $1^m\ 26^s$. Had the vessel been moving towards the weight the interval would have been increased and have been $1^m\ 54^s$.

It is obvious that the greater the tension of the sounding line the nearer the angle p_1p_2m, will approach a right angle, other things being the same; also, that the nearer p_1 is to P the nearer the angle p_1p_2m approaches a right angle; and it follows that in order to obtain great regularity in the intervals between the times of the marks on the sounding line passing over the pulley, the line should be kept as nearly vertical and with as great tension as possible. This is a very important consideration; because, as will be seen hereafter, the comparison of the observed intervals affords the means of calculating the depth, and therefore the more regular

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the intervals at the striking point are the more accurate will be the determination of the depth.

The sounding lines supplied to the *Hydra* were wound on reels each containing 1,000 fathoms.

We constructed a sounding reel larger and stronger than either of the above, and fitted a brake to govern the velocity of its rotation. This reel was capable of holding 1,500 fathoms of No. 2 line, or 2,000 fathoms of No. 3 line, with one or two hundred fathoms of No. 1 line bent to the outer end when the whole was wound tightly and evenly round the reel. Strings for tying on the deep-sea thermometer were inserted 50 fathoms from the outer end of No. 1 line, and in No. 2 at any desired position.

When more line was required to reach the bottom than the sounding reel contained one of the 1,000-fathom reels was placed on a stand which permitted it to revolve, the outer end of the line was taken round the engine pulley and bent to the inner end of the sounding line with a reef knot, the ends being stopped down.

The line was marked at the first hundred fathoms from its outer end with a piece of red bunting, at the second with white, at the third with blue, at the fourth with yellow, and so on, the colours recurring in order; halfway between each of the bunting marks a knot was placed to denote the 50 fathoms.

To measure the lines two pulleys were fixed so that three turns round them measured exactly 100 fathoms, hence by hauling the line round the pulleys when one of the 100 or 50 fathom marks was about to leave the pulley the next corresponding mark was coming on it, and if the line was correctly marked these marks met on the circumference of the pulley; if this was not the case by measuring the short distance between the marks and noting it the error was determined. Thus whilst reeling up the line its length at a given tension was correctly determined without occupying much more time than that necessary to wind the line tightly and evenly round the reel.

The sounding line was always coiled carefully down as it was hove in and was afterwards reeled up.

Besides the iron sinkers supplied we used shot in the following manner:—

Three 68-pound shot placed on the deck so as to touch each other left an aperture between them, the section of which by a plane passing through the points of contact is shown in (Fig. 10) by the triangle *abc*, bounded by three circular arcs. 32- or 24-pound shot placed four together on the deck in a similar

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manner (Fig. 11) gave a quadrangular aperture between the four points of contact.

The shot secured together in the above positions respectively formed the base of our shot sinkers. The tube for bringing up the bottom passing through the aperture, other shot were secured to and above the base in similar positions, by which means numerous sinkers differing in weight were formed and answered the purpose very well.

The soil brought up from the bottom in the tube was placed in small glass bottles with diluted spirits of wine; these bottles, which were neatly fitted in a box, had labels pasted on them on which the number of the sounding as recorded in the sounding book was noted together with the depth and position.

After leaving the Cape of Good Hope on our return to England the bottom water was preserved in a similar manner.

Towards the end of January 1868 the *Hydra* left Bombay and sounded across the Indian Ocean to Hullaniyah, and from thence to Aden, where she arrived early in March.

When it was necessary to sound, the sails if set were taken in and furled, except the jib, which was generally kept set with the sheet aft; the vessel was placed before the wind, the engines stopped and reversed, so as to keep the ship as nearly stationary as possible. This required great care and attention and was very important. In the meantime the line and sounding apparatus were prepared as before described.

When all ready the weight was lowered into the water until the thermometer strings came to a convenient position, when the thermometer was secured to the line and lowered into the water The line was then allowed to run and the time shown by the watch when each bunting mark passed the gin block at the end of the accumulator pendant noted; if it was necessary to attach a thermometer to any other part of the line in which strings had been inserted for the purpose, the velocity was gradually diminished and stopped in the desired position, the thermometer secured to the line which was again allowed to run, the time being noted.

To ascertain the instant of striking, the line was carefully watched and the time noted when the weight was considered to strike the bottom; but the line was permitted to run on until the next two marks had passed the pulley, the times of each being carefully noted. The four last times gave three intervals from which the depth was calculated; and consequently it was essential to keep the vessel steadily over the line; and the sounding reel under uniform condition, at these times.

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Referring to sounding book (*see* Appendix), Nos. 27, 28, 29, and 30, afford some examples of No. 3 line. Examining No. 27 we see that—

2,000 to 2,100 fathoms gave an interval of 183 seconds.
2,100 to 2,200 „ „ 231 „

Comparing previous intervals it will be seen that if the line had received no check between 2,100 and 2,200 fathoms the interval would have been about 187 seconds; it is therefore evident that the weight must have struck the bottom between the times of the 2,100 and the 2,200 fathom marks respectively passing the gin block.

It was found that at a depth of 2,000 fathoms No. 3 line running from the sounding reel as it was ordinary kept during these observations, and influenced only by its own weight hanging vertically in the water, 100 fathoms of the line passed through the gin block in $4^m\ 40^s$.

It was also observed that after the weight struck the bottom and the line was relieved from its immediate effect, its velocity gradually diminished until it acquired a velocity differing insensibly from that due to the weight of the line alone; and that about 10 fathoms of the line passed over the gin block pulley with this gradually diminishing velocity.

In order therefore to determine the length of the line from the gin block to the tube at the instant of striking—

Let x = number of fathoms of the line which passed through the gin block from the 2,100-fathom mark to the instant of striking.

y = number of fathoms which passed through the gin block from the time the velocity of the line was reduced to that due to the line alone until the 2,200-fathom mark passed through the block.

We have also 10 fathoms described with a velocity gradually diminishing from that x was described with to that with which y was described; and therefore the time of describing this 10 fathoms may be taken equal to that of describing 10 fathoms with a uniform velocity equal to the mean of the other two.

Hence we have—

interval with which x fathoms were described $= \frac{x}{100} 183^s$

Do. 10 „ „ $= \frac{232^s}{10}$

Do. y „ „ $= \frac{y}{100} 280^s$

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$$\therefore \frac{x}{100}\,183+\frac{y}{100}\,280+\frac{232}{10}=231$$

$$x+y=90$$

$$\therefore \frac{x}{100}\,280+\frac{y}{100}\,280=\frac{9}{10}\,280$$

$$\therefore x\,\frac{97}{100}=280-231-\frac{280-232}{10}=44 \text{ very approximately.}$$

$\therefore x=45$ fathoms very nearly.

and the 2,100-fathom mark was 45 fathoms beyond the gin block when the weight struck the bottom.

The instant of striking determined by feeling the line was $2^m\ 23^s$ after the 2,100-fathom mark had passed through the block; this gives $x=100\,\frac{143}{187}=77$ very nearly, which differs from the former by 32 fathoms.

Referring to No. 28 we have—

From 1,800 to 1,900 fathoms interval = 146 seconds.

„ 1,900 to 2,000 „ = 217 „

Hence taking similar symbols to the foregoing we obtain—

$$\frac{x}{100}\,146+\frac{y}{100}280+\frac{182}{10}=217$$

$$x+y=90$$

$$\therefore \frac{x}{100}\,280+\frac{y}{100}280=\frac{9}{10}280$$

$$\therefore x\,\frac{134}{100}=280-217-\frac{280-182}{10}$$

$$=63-10=53 \text{ nearly.}$$

$\therefore x=40$ very nearly.

The instant of striking given by feeling the line was $1^m\ 16^s$ after the 1,900-fathom mark had passed the gin block, which gave $x=100\,\frac{76}{146}=52$.

Here the difference is 12 fathoms.

No. 29 gives from 1,950 to 2,000, interval = 73 seconds.

„ 2,000 to 2,050 „ = 126 „

Therefore, using 50 fathoms instead of 100 and similar symbols, we get $\frac{x}{50}\,73+\frac{y}{50}\,140+\frac{106}{5}=126$

$$x+y=40$$

$$\therefore \frac{x}{50}140+\frac{y}{50}\,140=\frac{4}{5}140$$

$$\therefore x\,\frac{67}{50}=140-126-\frac{140-106}{5}$$

$$=14-7 \text{ very nearly.}$$

$\therefore x=5$ very nearly.

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The instant of striking given by feeling the line was 32s after the 2,000-fathom mark had passed the gin block, which gave $x=\frac{32}{150}100=20$ nearly.

Referring to No. 30 we see that the weight struck the bottom when the 1,800-fathom mark was at the gin block, and that both methods agreed.

The weight of the sinker in No. 27 was 112 lbs., and the difference in the depth, as determined by the two above described methods, was 32 fathoms.

In No. 28 the weight of the sinker was 168 lbs., and the difference was 12 fathoms.

In No. 29 the weight used was 168 lbs., and the difference 15 fathoms.

The weight used in No. 30 was 224 lbs., and the agreement exact.

This shows the advantage of increasing the weight of the sinker.

We shall find in Nos. 32 and 33 examples of No. 2 line. This line running over the pulley of the accumulator gin block and urged alone by the weight of 2,000 fathoms of the line hanging vertically described, under the circumstances, 100 fathoms in four minutes.

Referring to No. 32 we have—

From 1,800 to 1,900 fathoms interval = 157 seconds.
„ 1,900 to 1,950 „ = 89 „
„ 1,950 to 2,000 „ = 119 „

Taking x and y to denote quantities similar to the foregoing we have—

$$\frac{x}{50}79+\frac{y}{50}120+\frac{99}{5}=89$$

$$x+y=40$$

$$\therefore \frac{x}{50}120+\frac{y}{50}120=\frac{4}{5}120$$

$$\therefore x\frac{41}{50}=120+89-\frac{120-99}{5}$$

$$=31-4 \text{ very approximately.}$$

$$\therefore x=34 \text{ very nearly.}$$

Hence the weight struck the bottom when the 1,900-fathom mark was 34 fathoms beyond the gin block.

The instant of striking determined by feeling the line was 48 seconds after the time of the passage of the 1,900-fathom mark through the gin-block;

Hence $x=\frac{48}{158}100=30$ nearly.

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No. 33 gives from 1,500 to 1,600 fathoms interval = 142 seconds.
„ 1,600 to 1,700 „ = 172 „
and taking the interval of 100 fathoms when urged by the weight of the line alone to be 240 seconds, we have—

$$\frac{x}{100}142+\frac{y}{100}240+\frac{191}{10}=172$$

$$x+y=90$$

$$\therefore \frac{x}{100}240+\frac{y}{100}240=\frac{9}{10}240$$

$$\therefore x\frac{98}{100}=240-172-\frac{240-191}{10}$$

$$=68-5=63 \text{ approximately.}$$

The instant of striking determined by feeling the line was 123s after the passage of the 1,600-fathom mark through the gin block, which gives—

$$x=100\frac{123}{142}=86 \text{ nearly.}$$

In No. 32 the weight of the sinker was 224 lbs., and the difference of the two determinations was 4 fathoms.

In No. 33 the weight of the sinker was 168 lbs., and the difference between the two determinations 23 fathoms.

Which also shows the advantage of increasing the weight of the sinker.

We will now take some examples of No. 2 line from the Atlantic soundings.

Atlantic No. 1 gives from 1,800 to 1,900 fathoms interval = 117s
„ 1,900 to 1,950 „ = 108s
„ 1,950 to 2,000 „ = 124s

Taking similar symbols and 50 fathom intervals—

$$\frac{x}{50}59+\frac{y}{50}124+\frac{92}{5}=108$$

$$x+y=40$$

$$\frac{x}{50}124+\frac{y}{50}124=\frac{4}{5}124$$

$$x\frac{65}{50}=124-108-\frac{124-92}{5}$$

$$=16-6=10 \text{ nearly.}$$

$$\therefore x=8 \text{ nearly.}$$

Hence length of line from the gin block to the tube at the instant of striking = 1,908 fathoms.

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From Atlantic No. 2 we obtain—

From 2,200 to 2,300 interval = 107 seconds.
„ 2,300 to 2,400 „ = 151 „
100 fathoms by weight of line alone = 232 „

$$\text{Hence } \frac{x}{100}\,107+\frac{y}{100}\,232+\frac{170}{10}=151$$

$$x+y=90$$

$$\therefore \frac{x}{100}\,232+\frac{y}{100}\,232=\frac{9}{10}\,232$$

$$\therefore x\,\frac{125}{100}=232-151-\frac{232-170}{10}$$

$$=81-6 \text{ nearly.}$$

$$\therefore x=\frac{4}{5}\,75=60$$

Which gives length of line out at striking 2,360 fathoms.

Atlantic No. 4 gives—

From 2,400 to 2,500 interval = 117 seconds.
„ 2,500 to 2,600 „ = 138 „
„ 2,600 to 2,650 „ = 113 „

from which we derive—

$$\frac{x}{100}\,117+\frac{y}{100}\,226+\frac{172}{10}=138$$

$$x+y=90$$

$$\therefore \frac{x}{100}\,226+\frac{y}{100}\,226=\frac{9}{10}\,226$$

$$x\frac{109}{100}=226-138-\frac{226-172}{10}=88-5=83 \text{ approximately.}$$

$$\therefore x=83\frac{100}{109}=76 \text{ nearly.}$$

Which gives length of line at striking 2,576 fathoms.

Atlantic No. 5 gave—

From 2,700 to 2,800 interval = 137 seconds.
„ 2,800 to 2,900 „ = 179 „
„ 2,900 to 2,950 „ = 105 „

From which we obtain—

$$\frac{x}{100}\,137+\frac{y}{100}\,210+\frac{174}{10}=179$$

$$x+y=90$$

$$\therefore \frac{x}{100}\,210+\frac{y}{100}\,210=\frac{9}{10}\,210$$

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$$\therefore x\,\frac{73}{100} = 210 - 179 - \frac{210-174}{10}$$

$$= 31 - 4 = 27 \text{ nearly.}$$

$$\therefore x = 27\,\frac{100}{73} = 37 \text{ very approximately.}$$

Hence at the instant of striking the length of the line from the gin block to the tube was 2,837 fathoms.

Examining the above equations we perceive that the larger the coefficient of x, which results from the elimination of y, the more accurate will be the determination of x; and that the magnitude of this coefficient depends upon the difference between the first and last of the three intervals; that when the last interval has its greatest possible value, and the first has its least possible value, the value of x will be determined in the most accurate manner.

The first of these conditions is evidently satisfied when the last interval is infinite, or when the line stops upon the weight striking the bottom; the second will be satisfied by giving the greatest possible weight to the sinker.

Therefore the best result will be obtained by using the heaviest sinker the line is capable of sustaining, and resisting the descent by a force just sufficient to stop the motion upon the weight striking the bottom.

This agrees with the conclusion previously derived from other considerations.

The wind, unless blowing very strong indeed with a heavy sea, did not prevent us from obtaining a good sounding. Atlantic No. 5 was in the strength of the S.E. trade; during the sounding the sea washed over the poop, yet the vessel was kept steady with the line vertical. We got soundings in over 2,800 fathoms, and brought the bottom water and soil safely on board.

When we encountered a current difficulty and uncertainty commenced.

First. To keep the vessel steady against the resultant of the effects of the wind and current upon her, and that of the current upon the line, so that its direction at the surface of the sea should always be vertical, was a difficult operation which could only be approximated to. The Hydra's engines being inseparably connected increased the difficulty.

Secondly. The imperfect knowledge we could obtain of the depth, direction, and velocity of the current.

Thirdly. In deep currents the sinker frequently failed to disengage.

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Fourthly. Our imperfect knowledge of the nature and properties of the curve assumed by lines descending through a current rendered the corrections applied only very rough approximations.

The following considerations will give some idea of these difficulties, and the means necessary to surmount them.

Let the straight line S, S_1, S_2, represent (see Figure 12) the section of the surface of the sea by a vertical plane passing through the direction of a current running parallel to S, S_1, S_2, with a uniform velocity v through a given depth; and let Q, Q_1, Q_2, represent the intersection of the lower surface of the current by the same vertical plane.

If a lead of symmetrical form with respect to a vertical straight line through its centre of gravity, at the upper extremity of which a line is attached, dropped from a ship at S would, in still water, describe the vertical straight line SQ, equal to the depth of the current, in the same time the current would set the ship from S to S_1; draw $S_1Q_1q_1$ vertical, cutting QQ_1Q_2 in Q_1; therefore when the lead is dropped in the current it will arrive at Q_1 at the same instant that the ship arrives at S_1, after having described some curve SQ_1, to which let the straight line Q_1q be the tangent at Q_1; the lead will then leave the current and pass into the still water below it.

At this instant, if we suppose the line disengaged from the lead, we shall have the lead at Q_1 moving with a certain velocity in direction Q_1q, and acted upon by gravity and the resistance of the water, it will therefore tend to describe some curve Q_1B, in the plane of the paper convex to Q_1q, and concave to $S_1Q_1q_1$. If the line had remained attached to the lead and the velocity of the lead be resolved vertically and horizontally, it is clear that when the lead was at Q_1 its horizontal velocity was equal to the velocity of the current, and in the same direction; the ship was at S_1 moving with the current, the direction of the line being vertical. After passing Q_1 the motion of the lead will be retarded by the resistance of the still water, and therefore its horizontal velocity will gradually diminish, whilst the ship moving on with the current will no longer remain vertically over the lead, and the line will consequently be drawn out of the vertical inclining from the lead towards the ship in direction of the current, and the line will therefore tend to pull the lead in direction of the current and the ship against it, and in order to keep the line vertical she must begin to move against the current. The effect of the line upon the lead may be resolved into two forces, one vertical acting

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against gravity, the other horizontal tending to increase the velocity of the lead in direction of the current, and therefore the line will tend to pull the lead out of the curve Q_1B, and make it describe another curve Q_1PC, farther from Q_1q_1, than Q_1B.

Some time after the lead and the ship have respectively left Q_1 and S_1 let the lead be at P in the curve Q_1PC, and the ship at S_2, the line having some form PQ_2S_2, between them which cuts the common surface of the current and still water in Q_2. It is evident that the part S_2Q_2, of the line in the current will be urged along in direction of the current, and drag the part Q_2P, through the still water in the same direction; that the still water resisting this motion will make the line Q_2P assume a curved shape convex to the direction of the current, whilst the part S_2Q_2, retarded at Q_2 by the resistance of the part Q_2P, and pushed against the current at S_2 by the ship endeavouring to keep its direction vertical, will assume a curved shape concave to that direction.

If therefore v_1, v_2, v_3, to be respectively the velocities of S_2, Q_2, and that of P resolved horizontally, we shall have three velocities all gradually diminishing from the time of the ship and the lead respectively leaving the points S_1 and Q_1, where they were all equal to v.

We see, therefore, that v_1 and v_2 which were at first equal to v gradually diminish from that value; also that since the vessel always endeavours to keep the direction of the line at S_2 vertical any diminution of the value of v_2 must be followed by a proportional diminution of v_1; now v_2 continually diminishes from a fixed value v, and never actually reaches zero, therefore its decrement after a certain determinate time will become so small that the change in a given interval of time will be too small to have any practical effect on the form of S_2Q_2, and if it be the interval at which the value of v_1 follows that of v_2, at this instant and for any time after v_1 and v_2 may be considered equal, and the length of S_2Q_2, calculated on this supposition, will differ from its actual length by a quantity too small to be of any practical value.

Again, as the lead after entering the still water below Q_1 descends, the resistance of the water on the part PQ_2 will continually increase, and consequently the horizontal velocity of the lead v_3 will continually diminish, and, although v_3 will never absolutely vanish, there will be a position of the lead P suppose, after which v_3 will be so small as to be of no practical value, and

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the length Q_2P, given by the supposition $v_3 = 0$ will differ from its actual value by a quantity which is practically valueless, and when the lead is at any point p below P the length of the line Pp will give the vertical depth of p below P.

Next let S, S_1, S_2, Q, Q_1, Q, and Q, Q'_1, Q'_2, be the intersections of the respective surfaces of the sea, and of a current at a given depth below it running with a uniform velocity v through a given depth, by a vertical plane parallel to the direction of the current.

We will suppose S, S_1, S_2, Q, Q_1, Q_2, and Q', Q'_1, Q'_2, horizontal and SQQ′ vertical.

In a manner similar to the foregoing it may be shown that a lead descending from a ship S with a line attached to it will, after describing the vertical SQ, in still water whilst passing through the under current $QP^1Q'_1$, and after entering the still water below it, describe another curve Q'_1P_2pC, concave to the direction of the current, and of such a nature that at some point P_2 the direction of the lead's motion will be so nearly vertical that we may without practical error consider it so.

We have here supposed the current to run uniformly through a given depth, but if its velocity vary with the depth, a similar process of reasoning will lead to the conclusion that the line approximates to a fixed form as a limit given by considering the horizontal velocity of P zero, and that the length of the curved parts of the line calculated on this supposition will, if P be sufficiently deep, differ so little from their actual lengths that in practice this difference may be neglected. In (Figure 12) draw S_2NM vertical, cutting QQ_1Q_2 in N and PM horizontal in M; and in (Figure 13) draw NQQ'_2M vertical meeting SS_1S_2 produced in N and P_2M horizontal in M.

Hence we see that in a surface current of uniform rate v, and of a given depth d, we have first to determine the length S_2Q_2, for a line of the description used, in terms of d and $v - v_1$, this being subtracted from the whole length of the line out will give the length Q_2Pp, and therefore of Q_2P, if P be the point where we may consider P's horizontal motion to be zero; then the relation between the vertical NM, and Q_2P, being determined from the form the line would assume in a current running with a velocity v_1 at Q_2, and gradually diminishing to zero at P, with sufficient accuracy, we shall obtain NM, which added to S_2N, will give the vertical distance of P below the surface of the water with sufficient accuracy.

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the tension at S be al then $T=al$, and substituting in (1.), and observing that in this case $\phi x=1$, we obtain $l=v^2\rho\sin\theta$. (2.)

But $\frac{dx}{\rho d\theta}=-\sin\theta$,

$$\therefore d\theta=-\frac{v^2}{l}dx,$$

$$\therefore \theta=C-\frac{v^2}{l}x. \quad \text{When } x=0\ \theta=\frac{\pi}{2},$$

$$\therefore \frac{\pi}{2}=C,$$

$$\text{and } \frac{\pi}{2}-\theta=\frac{v^2}{l}x \qquad (3.)$$

If d be the depth of the current and α the value of θ at the lower surface of the current, then $\frac{\pi}{2}-\alpha=\frac{v^2d}{l}$ gives the deflection of the line from the vertical at the lower surface of the current.

If the tension of the line be made equal to the force necessary to hold a length of the line equal to d against the current impinging perpendicularly upon it when kept perfectly straight, then $l=v^2d$ and $\frac{\pi}{2}-\alpha=1$.

If we double the tension then $l=2v^2d$ and $\frac{\pi}{2}-\alpha=\frac{1}{2}$,

therefore by doubling the tension we halve the angle by which the line is deflected from the vertical; this shows the advantage of increasing the tension of a line when sounding in a current.

To determine the length of the line passing through the upper current when at equilibrium under the above supposition,

let SP$=s$ then $\frac{ds}{dx}=\operatorname{cosec}\theta$; from (3) we have

$$\theta=\frac{\pi}{2}-\frac{v^2x}{l}, \quad \therefore \frac{ds}{dx}=\sec v^2\frac{x}{l},$$

$$\therefore s=C+\frac{l}{v^2}\log_\epsilon\tan\left\{\frac{\pi}{4}+\frac{v^2x}{2l}\right\}$$

when $s=0$, $x=0$, $\therefore C=0$, and we have

$$s=\frac{l}{v^2}\log_\epsilon\tan\left\{\frac{\pi}{4}+\frac{v^2x}{2l}\right\}$$

$$=\frac{l}{v}\,\frac{\log\tan\left\{\frac{\pi}{4}+\frac{v^2x}{2l}\right\}}{0\cdot4343} \qquad (4.)$$

taking value of $\log_\epsilon$ to four places of decimals.

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Similarly referring to (Figure 13) we see that in an undercurrent the line will assume three curves, of which, when P is sufficiently deep, the limiting forms may be taken to calculate the length of S_2Q_2 from NQ_2, the depth of the current below the surface of the sea; that of $Q_2Q'_2$ from the vertical depth of the current combined respectively with the velocities v_1 and $v-v_1$; and subtracting $SQ_2Q'_2$, thus determined, from the length of whole line out we shall obtain the length of Q'_2P_2, from which Q'_2M may be determined as above.

It is hardly necessary to observe that v_1 is the velocity of the ship through the water.

We will now investigate the form of these curves.

Referring to rectangular axes of co-ordinates SY, SX (Figure 14), respectively horizontal and vertical, let SPQ be the curve which a line will assume when fastened at the points S and Q in the same vertical plane, and acted upon by a current of salt water running parallel to YS, the direction of the line at S being vertical; x, y, the co-ordinates of any point P in the curve, PT the tangent to it at P making an angle $PTS = \theta$ with the axis of y; T, the tension of the line at P, $v\varphi(x)$ the velocity of the current at P, v being the velocity of the current at the surface, and $\phi(x)$ a function of x of such a nature that $\phi(o)=1$, also let be the radius of curvature at P.

If a be the pressure that a current of salt water running with a unit of velocity exerts on a unit of length of the line held perpendicular to its direction and kept perfectly straight, the pressure of the water on a small piece of the line $\rho\delta\theta$ at P, arising from the current and resolved in direction of the normal, will equal $av^2\{\varphi(x)\}^2\rho \sin\theta\delta\theta$. Now the tension on the extremities of this small piece of line resolved in direction of the normal is $T\delta\theta$, and if we neglect the weight in water of the small piece of line as being very small when compared with the other forces acting upon it, we shall have—

$$T\delta\theta = av^2\{\phi(x)\}^2\rho\sin\theta\delta\theta,$$
$$\therefore\ T = av^2\{\phi(x)\}^2\rho\sin\theta \qquad (1.)$$

For a small depth, such as a surface current of uniform velocity throughout its depth, we may suppose the tension of the line to remain the same at all points from S to Q, and if the unit of tension be taken equal to the pressure that the water running with a unit of velocity exerts on a unit of length of the line held perpendicular to its direction and kept perfectly straight, and that

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Suppose $l=v^2d$, $v=1$ knot and $d=100$ fathoms.

Then substituting in (4) $SQ=100\frac{5326}{4343}=122{\cdot}6$, which exceeds the vertical depth by $22{\cdot}6$ fathoms.

Next let the tension be doubled or $l=2v^2d$, which gives—

$$SQ=200\frac{\log\tan(59^\circ\ 20')}{0{\cdot}4343}$$

$$=104{\cdot}5 \text{ fathoms}$$

$$\log\tan 59^\circ\ 20'=0{\cdot}22697 \quad \log=\bar{1}{\cdot}35603$$

$$200 \quad \log=2{\cdot}30103$$

$$\overline{1{\cdot}65706}$$

$$0{\cdot}4343 \quad \log=1{\cdot}63779$$

$$\overline{104{\cdot}5 \quad \log\ 2{\cdot}01927}$$

which exceeds the depth by $4{\cdot}5$ fathoms; comparing this with $22{\cdot}6$ it appears that by doubling the tension of the line, when tension $=av^2d$, the correction will be reduced to $\frac{1}{5}$th its former amount.

Friction and its effects on a Sounding Line.

Suppose the friction between the line and the water through which it is descending vertically to vary with the pressure, and that its force on a unit of length of the line under a pressure equal to that of a column of water of a unit of depth to be $2am$; then the force on an element δx at depth x below the surface of the water will be $2am(b+x)\delta x$, where b is the length of a column of water whose pressure is equal to that of the atmosphere, and therefore the whole force of friction from the surface to this point will be $amx(2b+x)$, and consequently if al be the tension of the line at the surface of the water, its tension at depth x below the surface will be, under the above supposition, $a\{l+mx(2b+x)\}$.

The line descending in a current will generally be curved, and consequently the force of friction will be greater than that given by the above expression, but will approach nearer to it as the curvature diminishes.

For the sake of simplicity we will take $T=a\{l+mx(2b+x)\}$, and substituting this value for T in (1) we shall obtain—

$$l+mx(2b+x)=v^2\rho\sin\theta \qquad (5.)$$

$$\therefore\ d\theta=-\frac{v^2}{m}\cdot\frac{dx}{x^2+2bx+\frac{l}{m}}$$

$$=-\frac{v^2}{m}\cdot\frac{dx}{(x+b)^2+\frac{l}{m}-b^2}.$$

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$$\therefore\ \theta = C - \frac{v^2}{m}\sqrt{\frac{m}{l-mb^2}}\tan^{-1}\sqrt{\frac{m}{l-mb^2}}\,(x+b),$$

when $x=0$, $\theta=\frac{\pi}{2}$,

$$\therefore\ \frac{\pi}{2}-\theta$$

$$=\frac{v^2}{m}\sqrt{\frac{m}{l-mb^2}}\left\{\tan^{-1}\sqrt{\frac{m}{l-mb^2}}(x+b)-\tan^{-1}\sqrt{\frac{mb^2}{l-mb^2}}\right\}\quad(6.)$$

To give a practical form to this result the values of m and l must be determined by experiment and the tension of the line observed.

From the rough experiments I was able to make which can only be considered as distantly approximate $m=\frac{1}{1000}$.

Let $d=100$ fathoms, $v=1$ knot, $l=v^2d$, and $b=5$ fathoms, substituting in (6.) we have—

$$\frac{\pi}{2}-\theta=\frac{1000}{\sqrt{99975}}\left(\tan^{-1}\frac{x+5}{\sqrt{99975}}-\tan^{-1}\frac{1}{\sqrt{3999}}\right),$$

$\log 99975 = 4{\cdot}999892$ $\log 3999 = 3{\cdot}601951$

$\log\sqrt{99975} = 2{\cdot}499946$ $\log\sqrt{3999} = 1{\cdot}800975$ adding 10 to index,

$\log\frac{1000}{\sqrt{99975}} = 0{\cdot}500054$, $\therefore \log\tan^{-1}\frac{1}{\sqrt{3999}} = 8{\cdot}199025$,

$$\therefore\ \tan^{-1}\frac{1}{\sqrt{3999}} = 0^\circ\ 54'.$$

The value of $\tan^{-1}\frac{x+5}{\sqrt{99975}}$ for $x=10, 20, \ldots$ to $x=100$ can be calculated as follows, remarking that four places of decimals will give the result with sufficient accuracy:—

$x=10$, $x+b=15$ $\log = 1{\cdot}1761$ $\angle\ 2^\circ\ 43'$

$\log\sqrt{99975} = 2{\cdot}4999$ $\quad -\ 54'$

$2^\circ\ 43'$ $\log\tan = \underline{\underline{8{\cdot}6762}}$ $\quad \underline{\underline{1^\circ\ 49'}} = 1^\circ{\cdot}817$ $\log = 0{\cdot}2593$

Constant $\log = 0{\cdot}5001$

$5^\circ{\cdot}75$ $\log\ \underline{\underline{0{\cdot}7594}}$

$$\therefore\ \frac{\pi}{2}-\theta = 5^\circ\ 45'.$$

$x=20$, $x+b=25$ $\log = 1{\cdot}3979$ $\angle\ 4^\circ\ 31'$

$\log\sqrt{99975} = 2{\cdot}4999$ $\quad -\ 54'$

$4^\circ\ 31'$ $\log\tan = \underline{\underline{8{\cdot}8980}}$ $\quad \underline{\underline{3^\circ\ 37'}} = 3^\circ{\cdot}617$ $\log = 0{\cdot}5583$

Constant $\log = 0{\cdot}5001$

$11^\circ{\cdot}44$ $\log\ \underline{\underline{1{\cdot}0584}}$

$$\therefore\ \frac{\pi}{2}-\theta = 11^\circ\ 26^1.$$

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In a similar manner we shall find,—

Depth below surface.	Angle of Deflection from Vertical.
	° ′
30 fathoms	17 7
40 „	22 50
50 „	28 25
60 „	33 51
70 „	39 26
80 „	44 50
90 „	50 4
100 „	55 17

In order to determine approximately the length of the line from the upper to the lower surface of the current, we can calculate the elongation of every ten fathoms due to the mean deflection of the line, and by adding them together obtain very nearly the number of fathoms by which the line in the current exceeds the *vertical* depth, as will be seen in the following table:—

Depth below Surface.	Mean Deflection.	Elongation.
	° ′	
From 0 to 10 fathoms	2 53	0·01266 fathoms
„ 10 „ 20 „	8 36	0·11244 „
„ 20 „ 30 „	14 29	0·31780 „
„ 30 „ 40 „	19 59	0·60218 „
„ 40 „ 50 „	25 38	0·98419 „
„ 50 „ 60 „	31 8	1·44034 „
„ 60 „ 70 „	36 38	1·97529 „
„ 70 „ 80 „	42 8	2·58414 „
„ 80 „ 90 „	47 27	3·23767 „
„ 90 „ 100 „	52 40	3·93549 „
	Total Elongation	15·10220 fathoms

Hence the length of line in the current in this case is 115 fathoms; comparing this with case where the friction was supposed not to act we see that other circumstances being the same the effect of friction is to shorten the line in the current and also to diminish the angle of deflection.

With regard to the line below the surface of the current, we have seen that its horizontal velocity continually diminishes as the depth below the lower surface of the current increases, and that at some large depth z suppose below this surface, we may consider the horizontal velocity as practically valueless. If therefore v_1 be the horizontal velocity of the line at the lower surface of the current, its horizontal velocity at depth x below the lower surface of the current may be represented by $v_1\left(1-\frac{x}{z}\right)$; introducing this value instead of v in (5.) we obtain—

$$l+mx(2b+x)=v_1^2\left(1-\frac{x}{z}\right)^2\rho\sin\theta \qquad (7.)$$

which very nearly expresses the condition of a line descending below the surface of a current running uniformly through a given depth with a velocity $v+v_1$. Observing that the line curves in

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the opposite direction from the part in the current above it we get—

$$d\theta = \frac{v_1^2}{mz^2} \cdot \frac{(x-z)^2 dx}{x^2+2bx+\frac{l}{m}}$$

$$= \frac{v_1^2}{mz^2}\left\{1 - \frac{2(z+b)(x+b)}{x^2+2bx+\frac{l}{m}} + \frac{2b(z+b)+z^2-\frac{l}{m}}{(x+b)^2+\frac{l}{m}-b^2}\right\}dx$$

From the nature of the case l is always greater than mb^2;

$$\therefore \theta = C + \frac{v_1^2}{mz^2}\left\{x-(z+b)\log_\epsilon\left(x^2+2bx+\frac{l}{m}\right)\right.$$
$$\left.+\left((z+b)^2+b^2-\frac{l}{m}\right)\sqrt{\frac{m}{l-mb^2}}\tan^{-1}\sqrt{\frac{m}{l-mb^2}}(x+b)\right\}$$

By supposition when $x=z$, $\theta=\frac{\pi}{2}$;

$$\therefore \frac{\pi}{2}-\theta = \frac{v_1^2}{mz^2}\left\{z-x-(z+b)\log_\epsilon\frac{z^2+2bz+\frac{l}{m}}{x^2+2bx+\frac{l}{m}}\right.$$
$$+\left((z+b)^2+b^2-\frac{l}{m}\right)\sqrt{\frac{m}{l-mb^2}}\times$$
$$\left.\times\left(\tan^{-1}\sqrt{\frac{m}{l-mb^2}}(z+b)-\tan^{-1}\sqrt{\frac{m}{l-mb^2}}(x+b)\right)\right\} \quad (8.)$$

gives the deflection of the line from the vertical at depth x below the lower surface of the current.

Let $l=2dv^2$, and as before $v=1$, $d=100$, $m=\frac{1}{1000}$. Here $b=105$, and if $z=2000$, substituting in (8.), we shall get—

$$\frac{\pi}{2}-\theta = \frac{v_1^2}{4000}\left\{2000-x-2105\log_\epsilon\frac{23{\cdot}1}{\frac{1}{20}\left(\frac{x}{100}\right)^2+\frac{21}{200}\frac{x}{100}+1}\right.$$
$$\left.+\frac{4242050}{\sqrt{188975}}\left(\tan^{-1}\frac{2105}{\sqrt{188975}}-\tan^{-1}\frac{x+105}{\sqrt{188975}}\right)\right\};$$

$$\therefore \frac{\pi}{2}-\theta$$
$$= v_1^2\left\{\tfrac{1}{2}-\frac{x}{4000}-\frac{421}{800}\frac{\log_{10}23{\cdot}1-\log_{10}\left\{\frac{1}{20}\left(\frac{x}{100}\right)^2+\frac{21}{200}\left(\frac{x}{100}\right)+1\right\}}{0{\cdot}4343}\right.$$
$$\left.+\frac{84841}{80\sqrt{188975}}\left(\tan^{-1}\frac{421}{\sqrt{7559}}-\tan^{-1}\frac{x+105}{\sqrt{188975}}\right)\right\} \quad (9.)$$

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To find value of v_1 by making $l=2dv^2$ in (6.) we get the angle of deflection of the line at the lower surface of the current to be 28°. 12, and this must therefore be the value of $\frac{\pi}{2}-\theta$ in (9.) when $x=0$; introducing this condition in (9.) we shall obtain the value of v_1;

$$\therefore 28°\cdot 12 = v_1^2\left\{\tfrac{1}{2}-\frac{421}{800}\cdot\frac{\log_{10}23\cdot1}{0\cdot4343} + \frac{84841}{80\sqrt{188975}}\left(\tan^{-1}\frac{421}{\sqrt{7559}}+\tan^{-1}\frac{21}{\sqrt{7559}}\right)\right\}.$$

Log $23\cdot1 = 1\cdot3636$ log $= 0\cdot13469$ log $421 = 2\cdot62428$

$0\cdot4343$ $= \bar{1}\cdot63779$ $800 = 2\cdot90309$

$0\cdot49690$ Con. log $= \bar{1}\ 72119$

Constant log $= \bar{1}\cdot72119$

log $0\cdot21809$

$1\cdot6523$

$-\frac{1}{2} = 0\cdot5000$

$1\cdot1523$ log $= 0\cdot0616$

log $57°\cdot3$ $= 1\cdot7582$

$\angle$ $66°\cdot04$ $= 1\cdot8198$

log $188975 = 5\cdot276402$

log $\sqrt{188975} = 2\cdot638201$

log 80 $= 1\cdot90309$

$4\cdot54129$

log 84841 $= 4\cdot92860$

Const $= \frac{84841}{80\sqrt{188975}}$ log $0\cdot38731$

log $421 = 2\cdot62428$ log $7559 = 3\cdot878464$

$1\cdot93923$ log $\sqrt{7559} = 1\cdot939232$

log tan $= 10\cdot68505$ log 21 $= 1\cdot32222$

$= 78°\ 20'$ log tan $= 9\cdot38299$

$-13°\ 34'\cdot5$ $= 13°\ 34'\cdot5$

$64°\ 45'\cdot5$

$64\cdot758$ log $= 1\cdot81129$

Constant log $= 0\cdot38731$

$\angle = 157°\cdot98$ $= 2\cdot19860$

$-\ 66°\cdot04$

$91°\cdot94$

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$\therefore\ 28°\cdot12 = v_1^2\ 91°\cdot94$ $\qquad \log 28\cdot12 = 1\cdot4490$

$-91\cdot94 = 1\cdot9635$

$\log v_1^2 = \bar{1}\cdot4855$

$\log v_1 = \bar{1}\cdot74275$

Hence $v_1 = 0\cdot553$ and $v + v_1 = 1\cdot553$ knots.

In order to calculate the deflection of the line for every 100 fathoms below the surface of the current we must substitute this value of v_1^2 in (9.) and make $x = 100$, 200 &c. fathoms.

Let $x = 100\ \therefore \frac{x}{4000} = \frac{1}{40}$ and $\frac{1}{2} - \frac{1}{40} = \frac{19}{40} = 0\cdot475$,

$$\frac{1}{20}\left(\frac{x}{100}\right)^2 + \frac{21}{200}\,\frac{x}{100} + 1 = \frac{1}{20} + \frac{21}{200} + 1 = \frac{231}{200},$$

and $\log 23\cdot1 - \log \frac{231}{200} = \log 20 = 1\cdot3010$ $\qquad \log 0\cdot11428$

$0\cdot4343$ $\qquad \log \bar{1}\cdot63779$

$\qquad\qquad 0\cdot47649$

Constant log $= \bar{1}\cdot72119$

$1\cdot576$ $\qquad \log 0\cdot19768$

$-0\cdot475$

$1\cdot101$

$\log 1\cdot101 = 0\cdot0418$

$\log 57°\cdot3 = 1\cdot7582$

$63\cdot1 \quad \log = 1\cdot8000$

$\log 41 = 1\cdot61278$

$\log \sqrt{7559} = 1\cdot93923$

$9\cdot67355$ $\log \tan \left\{ \tan^{-1} \frac{41}{\sqrt{7559}} \right\}$

$$\therefore \tan^{-1} \frac{41}{\sqrt{7559}} = 25°\ 15'$$

Constant $\angle\ 78°\ 20'$

$-\angle\ 25\cdot15$

$53\cdot5 = 53°\cdot08$ $\qquad \log = \bar{1}\cdot72493$

Constant log $= 0\cdot38731$

$\angle\ 129°\cdot5$ $\qquad \log = \bar{2}\cdot11224$

$-\ 63\cdot1$

$=\ 66\cdot4$ $\qquad \log = 1\cdot8222$

v_1^2 $\qquad \log = \bar{1}\cdot4855$

$20°\cdot31$ $\qquad \log = 1\cdot3077$

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$\therefore \left\{\frac{\pi}{2} - \theta\right\}_{x=100} = 20° 19'$. Pursuing this method we shall obtain as follows.—

Depth below Current.	Angle of the Line's Deflection from the Vertical.	Mean angle Deflection.	Elongation of Line.
	° ′	° ′	
0 fathoms -	28 7	24 13	8·7999 fathoms
100 „ -	20 19	17 21	5·5499 „
200 „ -	14 23	12 15	2·2769 „
300 „ -	10 6	8 35	1·1200 „
400 „ -	7 5	6 2	0·5509 „
500 „ -	4 59	4 13	0·2707 „
600 „ -	3 28	2 56	0·1310 „
700 „ -	2 24	—	—
		Sum	18·6993 „

We may therefore take the total elongation as 19 fathoms.

The length of the line in the current at this tension, viz., when $l = 2dv^2$ will be found to be 104 fathoms. The length of line below the surface of the current at a depth of 2,000 fathoms will be 2019, and therefore the whole length of line out at 2100 below the surface of the sea will be 2123, and the correction to be applied, the depth given by the time intervals, will be 23 fathoms.

Referring to the above table it will be seen that the deflection of the line below 700 fathoms is so small that it may be neglected without sensible error.

The above shows the great importance of keeping the line when sounding in a current at a judicious tension, and this tension should not be less than the force necessary to keep at equilibrium against the current a length of the line equal to the depth of the current, supposed perfectly straight and perpendicular to the direction of the current.

The instant the weight strikes the bottom a change in the shape and length of the line below the lower surface of the current immediately commences, and in order that the curve in the current may maintain its shape and dimensions the velocity of the vessel through the water and the tension of the line must gradually increase, the former from v to $v + v_1$, and the latter from al to $al\left\{1 + 2\frac{v_1}{v} + \left(\frac{v_1}{v}\right)^2\right\}$; and when the position of equilibrium is attained with the end of the line to which the tube is attached just resting upon the bottom, and the part of it below the current drawn out straight or nearly so in the direction the line has at the lower surface of the current, its length from the lower surface of

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the current to the bottom will have increased from 2,019 to 2,279 fathoms.

Now suppose the tension of the line necessary to raise the tube off the bottom at a depth of 2,000 fathoms to be $5ad(v+v_1)^2$, this tension will reduce the curvature of the line in the current, so that its length will now be 103 fathoms and its angle of deflection from the vertical at the lower surface of the current to 11° 40′; so that now the length of the line between the lower surface and the bottom will be reduced to 2042, and the correction in this case will be 45 fathoms, to be applied to the depth given by the accumulator.

The above points out the great importance of being able to determine and regulate the tension of the sounding line at any instant during the process of sounding; also of determining the force necessary to keep a fathom of the sounding line at equilibrium against a current running one knot and impinging perpendicularly upon the line supposed perfectly straight.

Referring to (3.) we see that when the line is at equilibrium in a surface current running uniformly through a given depth that $\frac{\pi}{2} - \theta = \frac{v^2 x}{l}$, which stated in practical language amounts to this, that other things remaining the same the deflection of the line from the vertical at any point in it varies inversely as the tension of the line; consequently if the tension be doubled the angles at which the line is inclined to the vertical at all the corresponding points throughout the line will be halved.

This condition will enable the depth of the current and the depth of the water to be calculated from observing the tensions corresponding to the different lengths of line out whilst heaving in the line very slowly before the tube is raised from the bottom, the line at the ship being kept vertical by the ship going through the water against the current.

Let a_1 be the length of the line reduced to the measuring tension under the above circumstances, when the observed tension was T, and when the tension had increased to 2T, let a_2 be the length of the line out reduced also to the measuring tension. Then if 2θ be the angle at which the line at the lower surface of the current was inclined to the vertical in the first case, θ will be the angle when tension was 2T, and since the vertical depth was the same in both cases, if we assume,—

$$a_1 \cos 2\theta = a_2 \cos \theta_1 \qquad (\alpha)$$

θ_1 will differ but little from θ, and may be taken as a first approximation.

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To determine θ_1, referring to (α) we obtain,

$$a_1(\cos^2\theta_1 - \sin^2\theta_1) = a_2\cos\theta_1,$$

$$\therefore \cos^2\theta_1 - \frac{a_2}{2a_1}\cos\theta_1 = \tfrac{1}{2},$$

$$\therefore \cos\theta_1 \pm \frac{a_2}{4a_1} = \pm\frac{\sqrt{8a_1^2 + a_2^2}}{4a_1},$$

The negative sign being inadmissible—

$$\cos\theta_1 = \frac{a_2}{4a_1}\left\{1 + \sqrt{1+8\left(\frac{a_1}{a_2}\right)_2}\right\} \quad ()$$

Let $\tan^2\phi = 8\left(\frac{a_1}{a_2}\right)^2 \quad \therefore \sec^2\phi = 1+8\left(\frac{a_1}{a_2}\right)^2$

$$\sec\phi = \tan^2\psi, \text{ then } \cos\theta_1 = \frac{a_2\sec^2\psi}{4a_1} \quad (\gamma)$$

in a form adapted to logarithms.

Suppose the velocity of the current and ship to be 1·553 knots. That when the tension of the line shown by the accumulator was 100 lbs., the length of the line out when reduced to the measuring tension was 2,383 fathoms; the line being then hove in *very* slowly, stopping occasionally and carefully determining the tension of the line. When the tension of the line had arrived at 200 lbs., suppose the length of the line out when reduced to the measuring tension to be 2,165 fathoms, and suppose that from experiments made on the line we had determined that at tension 100 lbs., $\frac{l}{(1\cdot553)^2} = 200$, then at tension 200 lbs. $\frac{l}{(1\cdot553)^2} = 400$.

Referring to equations (α), (β), (γ), and replacing a_1 by 2383, and a_2 by 2165, the value of θ_1 will be determined as follows:—

Log 2383 =	3·37712	
log $\sqrt{8}$ =	0·45154	
	3·82866	
log 2165 =	3·33546	
log tan ϕ =	10·49320	
log sec ϕ =	10·51452	
log tan ψ =	10·25726	
log sec ψ =	0·31520	log 4 = 0·60206
	= 0·31520	log 2383 = 3·37712
log 2165 =	3·33546	log $4a_1$ = 3·97918
	3·96586	
	3·97918	
	9·98668	log cos θ_1 = 14°·7′

But if d be the depth of the current $\theta = \frac{v^2 d}{l} = \frac{d}{400}$,

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$\therefore$ First approximation $d = 400 \cdot \theta_1$ $\log 400 = 2 \cdot 60206$

$\log 14^\circ \cdot 12 = 1 \cdot 14984$

$3 \cdot 75190$

$\log 57^\circ \cdot 3 = 3 \cdot 75816$

$98 \cdot 6$ $\log = 1 \cdot 99374$

gives depth current 98·6 fathoms.

Referring to (4.), we have for the length of the curved part of the line in the current at the two observations respectively—

$$s_1 = 200 \frac{\log \tan 59^\circ 7'}{0 \cdot 4343}$$

$$= 102 \cdot 7 \text{ fathoms.}$$

$\therefore$ $a_1 - s_1 = 2280.$

$$s_2 = 400 \frac{\log \tan 52^\circ 3 \cdot 5'}{0 \cdot 4343}$$

$$= 99 \cdot 6 \text{ fathoms.}$$

$\therefore$ $a_2 - s_2 = 2065.$

Substituting these values for a_1 and a_2 respectively in above, we obtain θ_2, which will approach nearer to θ than θ_1, but upon the opposite side; viz., if θ_1 be less than θ θ_2 will be larger than θ.

$\log \overline{a_1 - s_1} = 2280 = 3 \cdot 35793$

$\log \sqrt{8} = 0 \cdot 45154$

$3 \cdot 80947$

$\log \overline{a_2 - s} = 3 \cdot 31492$

$\log \tan \phi = 10 \cdot 48455$

$\log \sec \phi = 10 \cdot 51570$

$\log \tan \psi = 10 \cdot 25785$

$\log \sec \psi = 0 \cdot 31564$ $\quad$ $\log 4 = 0 \cdot 60206$

$0 \cdot 31564$ $\quad$ $\log a_1 - \theta_1 = 3 \cdot 35793$

$\log \overline{a_2 - s_2} = 3 \cdot 31492$ $\quad$ $3 \cdot 95999$

$3 \cdot 94620$

$3 \cdot 95999$

$9 \cdot 98621$ $\quad$ $\cos \theta_2 = 14^\circ \ 21\frac{1}{2}'$

Hence second approximation $d = \frac{14 \cdot 36}{57 \cdot 3} 400$ $\quad$ $\log 400 = 2 \cdot 60206$

$= 100 \cdot 25$ fms. $\quad$ $\log 14 \cdot 36 = 1 \cdot 1571$

$3 \cdot 75921$

$\log 57 \cdot 3 = 1 \cdot 75816$

$\log 100 \cdot 25 = 2 \cdot 00105$

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$$\text{Second approximation } s_2 = 400 \frac{\log \tan 52^\circ\ 10'\frac{3}{4}}{0{\cdot}4343}$$

$$= 101{\cdot}1 \text{ fathoms.}$$

$$\therefore\ a_2 - s_2 = 2165 - 101 = 2064.$$

$$\text{Depth below current} = 2064 \cos 14^\circ\ 21'\tfrac{1}{2}$$

$$= 1999{\cdot}5 \text{ fathoms.}$$

Depth of current = 100·25 „

Whole depth, 2nd approximation = 2099·75 „

The exact depth was 2100, as in the former example.

The cup lead of one hundred weight sent out to us gave very good results with No. 2 line in about 1,000 fathoms, generally bringing up a good allowance of bottom soil, and I believe the same line with a similarly formed lead of 2 cwt. will give good results in 2,000 fathoms.

The line to be used for deep sounding should be carefully made of the best material, similar to those sent to the Hydra, Nos. 1, 2, and 3; of these No. 2 with 200 fathoms of No. 1 at its outer end was found well adapted for general work; it was capable of bringing 300 lbs. up from 2,000 fathoms, without injurious straining.

When an increased duty is required to be performed, either as regards an increase in the depth of the sounding or of velocity in a current, it can always be met by increasing the size of the line and using proportional weights.

The line should be carefully marked and measured when at a given tension, and its extension corresponding to different degrees of tension ascertained and tabulated; it should then be tightly and evenly wound on a well-balanced reel of large diameter capable of revolving freely, but whose velocity of rotation is governed by a carefully adjusted brake.

A pulley should be placed between this reel and the gin block at the end of the accumulator pendant, round which a turn of the sounding line should be taken.

An accumulator should be fitted so as to show accurately at any instant the strain on the sounding line.

The line should never be permitted to run free, but be kept at a tension depending upon the circumstances of the sounding, viz., when there is no current the tension of the line should be equal to the weight in water of a length of the line equal to the depth of the expected sounding; when in a surface current of velocity v and depth d this tension should be increased by adv_2; when the weight has struck the bottom this tension should be doubled.

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When the sounding line has run out to near the expected depth very great care should be taken to keep the vessel perfectly steady, the line vertical and of uniform tension determined as above; the times of each 50-fathoms mark passing the gin block should now be carefully noted, and after the weight has struck the bottom two of these marks should be permitted to pass the gin block before altering the conditions of the sounding reel and the times noted; if, however, the line stops soon after the weight strikes the bottom, which it will do under favourable circumstances, it is obvious that these marks will not pass the gin block; but, in this case, the length of the line at the instant of striking will be given without using the time intervals, which would otherwise be essential to its determination.

Careful experiments on lines will enable tables to be constructed by which from the observed tensions and lengths of the line, and the velocity of the vessel through the water, the depth of the sounding and also the mean depth of the current may be taken by inspection.

When sounding in a current the weight of the tube should be increased so as to be greater than $4adv^2$; in fact, it will be better in all cases to make the tube sufficiently heavy to insure the instant of its being raised from the bottom being indicated by a sensible extension of the accumulator.

P. Fredk. Shortland,
Captain.

1, Pomeroy Villa, Totnes,
4th December 1868.

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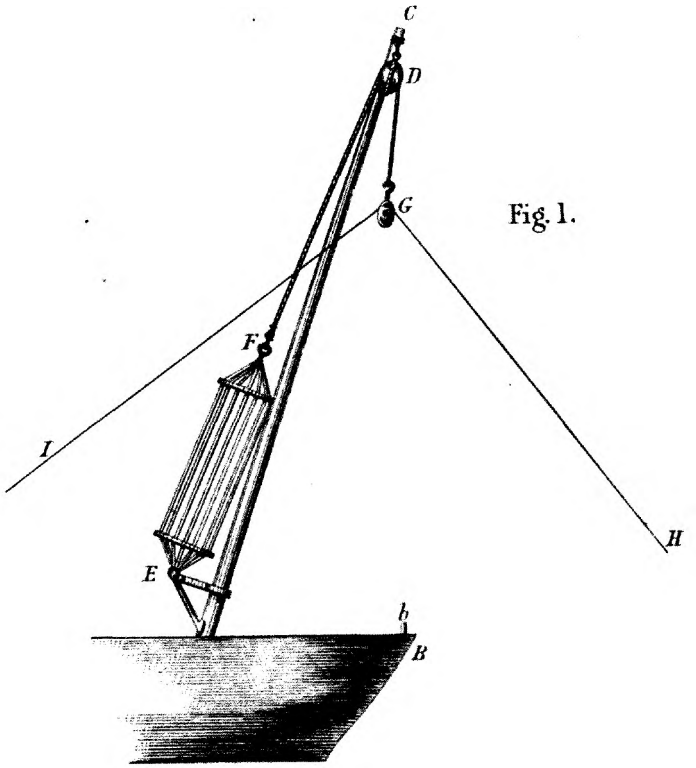

Fig. 1.

Fig. 2.

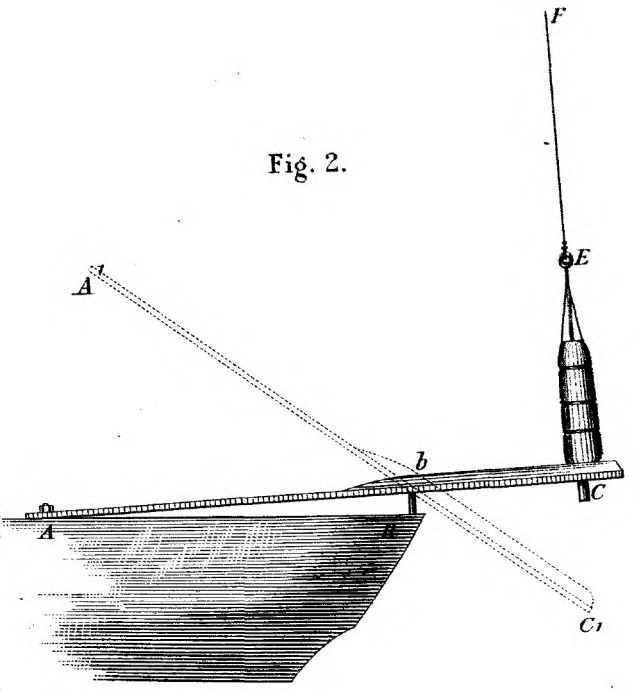

Fig. 3.

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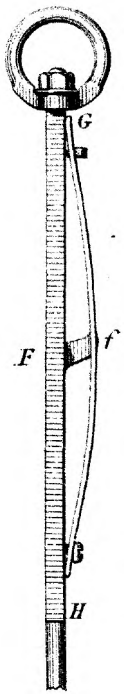
Fig. 4.

Fig. 5.

Fig. 6.



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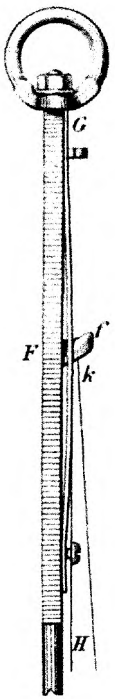
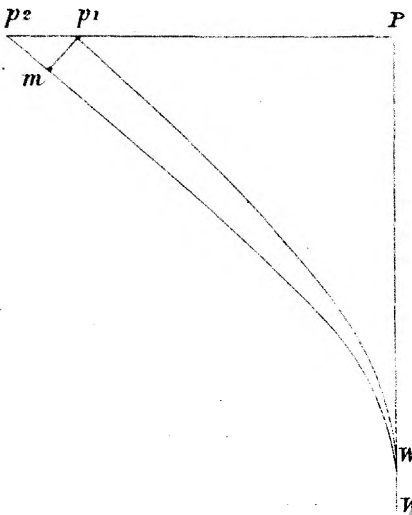


Fig. 9.



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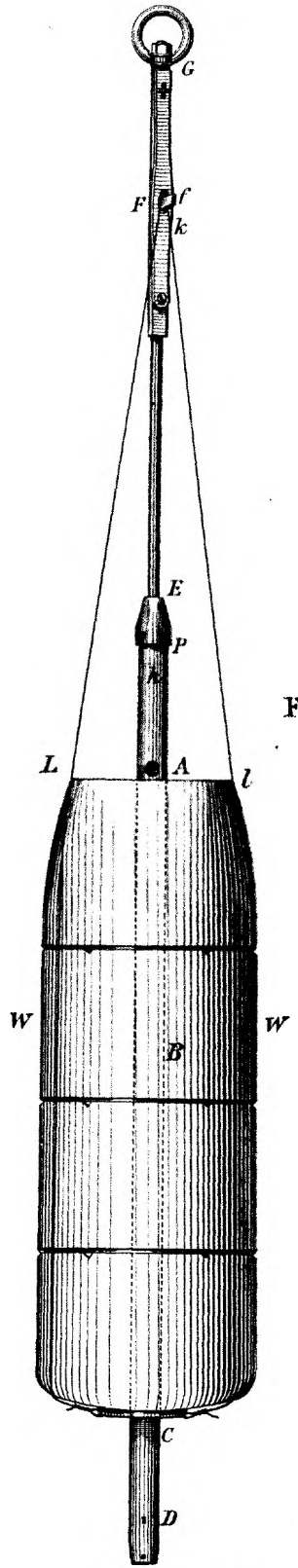

Fig. 8.

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Fig. 10.

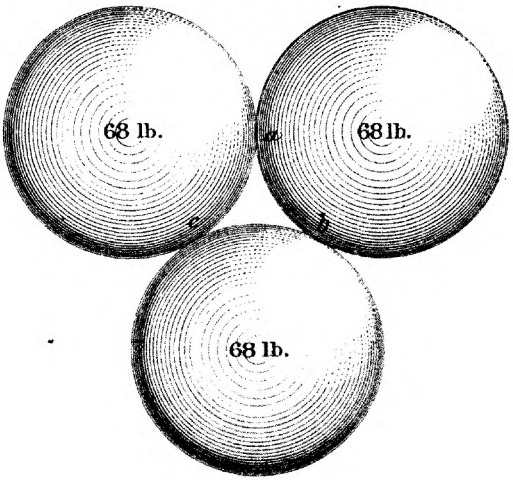
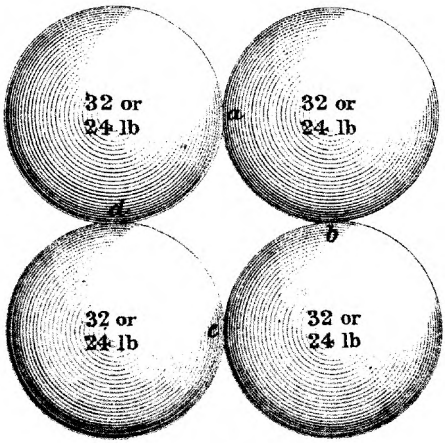


Fig. 11.



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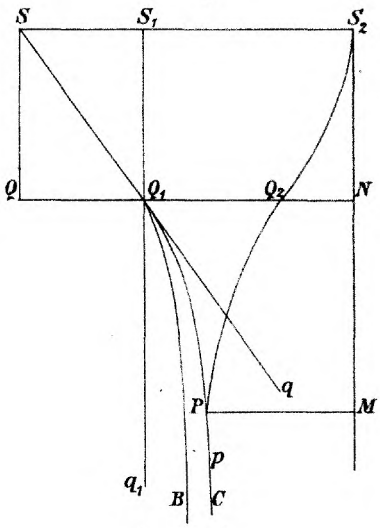


Fig. 13.

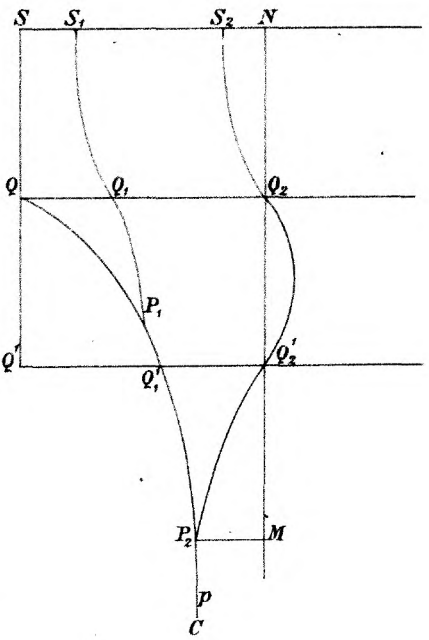
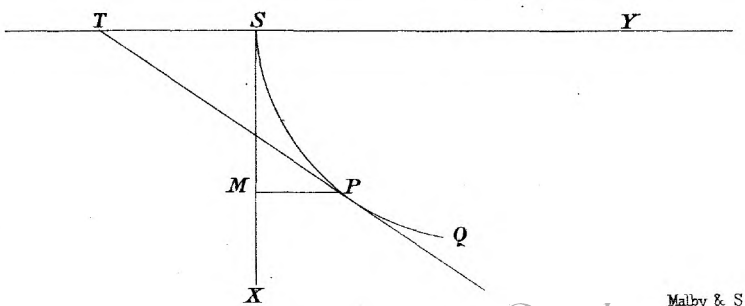


Fig. 14.



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APPENDIX.

Hydrographical Instructions.

24th September 1867.

The *Hydra* should leave Gibraltar as early as possible in October, and make the best of her way to Bombay, calling at St. Vincent and Simons Bay for fuel, &c.

Favourable winds may be expected in October from Gibraltar to the Cape Verdes; from thence it would be desirable to make a southerly course, steaming through the belt of Variables, which would be found well to the northward, and crossing the Equator, in about 25° of west longitude.

From here if the south-east trade is found strong it is recommended to stand to the S.S.W. across it, well full; but under any circumstances it is probable, with the occasional aid of steam, Trinidad would be weathered, crossing the 10th meridian in about 36°; from thence to the Cape fresh westerly winds would probably be experienced.

This route is recommended in preference to the inshore one along the coast of Africa, where the winds, after leaving the Bight of Biafra, would be unfavourable to southerly progress.

From the Cape of Good Hope I should recommend getting as soon as possible into about the 39th parallel, and making easting on it until in about the meridian of 65° E., then to make the northing, using steam whenever necessary if the stock on board would justify it, bearing in mind that the N.E. monsoon will probably be found light and unsteady; and as the deep soundings across the Arabian Gulf can only be obtained during this monsoon it will be necessary to use every exertion to reach Bombay by the end of December.

The sounding gear, which is being specially prepared for this service, will be sent to Gibraltar by the present mail, or such of it as may not be ready will be despatched by Suez to Bombay to meet the *Hydra* on her arrival. Lists of the articles sent are forwarded herewith.

You will also receive by this opportunity a printed paper drawn up in this department, containing all the information we possess on the mode of obtaining deep-sea sounding, together with lithograph descriptions of the various leads and instruments sent, and forms for registering the soundings; and I should wish you on the conclusion of the service to make a full report of the efficiency of the different instruments tried, and to forward such a detailed statement of the method pursued by you as may form a guide in any similar cases to be undertaken in future.

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You will likewise receive with this a set of charts, on which are shewn approximately the course over which it is proposed to lay the cable, and which requires to be sounded; they may properly be divided into two stages, viz., from Bombay to the Kuriyan Muriyan islands, and from thence on to Aden.

Over the first stage, a distance of about 950 geographical miles, the depth will probably be found not to exceed 2,000 fathoms, if we may judge from a deep cast obtained by Captain Pullen in the "Cyclops," of 1,880 fathoms, somewhere about the centre of the gulf. I should consider that if you obtained a positive sounding at intervals of every 50 or 60 miles it would be ample; but whether you are able to obtain so many must depend on the progress you make, for the whole work must be completed before the setting in of the S.W. monsoon at the end of April, or certainly not later than the middle of May.

It will be necessary when practicable to obtain specimens of the bottom and temperatures, for which latter purpose I send you a supply of deep-sea thermometers under the personal charge of Mr. Martin, navigating lieutenant.

As regards the line from the Kuriyan Muriyan islands to Aden, although the distance is less, being about 700 miles, it will probably occupy more time. You will observe that deep soundings are already shewn on the charts of this coast, but that they are very irregular in their depths; and it is considered objectionable to lay a submarine cable over such ground, not only from the injury likely to occur from the cable lying on an uneven rocky bottom, but also from the difficulty of grappling for it on the edge of a steep incline.

The object, then, is to discover if possible a comparatively level plateau of soft bottom; about 1,000 fathoms would be a convenient depth, and indeed a much greater depth would be considered preferable to the irregularity of the bottom, as shewn by the chart. The number of soundings you are able to obtain on this line must, in like manner, be determined by the time at your disposal, but it will be necessary occasionally to carry off a cross section, say for a distance of 30 miles, in order to ascertain the nature of the incline, especially in the vicinity of precipitous capes, such as Ras Nus and Morbat, Ras Fartak, &c.

In regard to the amount of accuracy necessary in depth and position of the soundings I will only say that in great depths an error of one or two hundred fathoms would appear to be of no practical consequence, and that it would be unnecessary to devote time to extreme accuracy of position beyond what would probably be obtained by the vessel hereafter employed in laying the cable. These points at any rate must be considered subordinate to the actual obtaining of the soundings.

Your attention will be sufficiently occupied with the work thus set forth, and I will therefore not divert it to any objects not immediately bearing upon that work, but any observations you are able to make on the set or strength of the surface current during the N.E. monsoon will be interesting and valuable, and if you should pass near to the

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position assigned to the Jack reef on the sheet of the Indian Ocean, No. 748*a*, it would be desirable to ascertain its existence or otherwise, and to get a deep cast of the lead, or two, in the neighbourhood.

On your return, especially if you should pass inside the island of Madagascar, I should be glad of any observations on the strength and direction of the currents near the coast in the neighbourhood of Natal, or to the northward, with the temperatures of the sea, and any deep soundings you may be able to obtain across the Agulhas Bank ; and in relation to this I would ask your attention to the new chart of South Africa lately published, No. 2095, as well as to the Ice chart of Southern Hemisphere, No. 1241.

It seems probable that under favourable circumstances you would reach Bombay about the close of December, and be enabled, after such a refit as may be necessary, and embarking your sounding stores and all possible coal, to start early in January to commence the soundings.

The 100-fathom bank extends westward of Bombay for about 150 miles, and over this distance it would only be necessary to verify the depth and nature of the bottom without any detention ; but as the shore end of the cable would probably be landed somewhere about Mahun, 10 miles northward of the harbour, in order to avoid vessels' anchors ; it would be well if during your stay at Bombay you were able to make an examination off this locality either by boat or small craft.

I anticipate that you would carry sufficient coal from Bombay to perform the whole service, but you may confidently rely on obtaining any quantity at Aden, as well as supplies. If, therefore, you found yourself running short, it would be well to push on to Aden ; and, after coaling, carry the line back eastward to where you had discontinued it.

It would be unnecessary, so far as I am able to foresee, for you to return to Bombay after having once left it, but you would make Aden your final port of departure for England.

At both places you may calculate on receiving any further instructions that may be necessary.

GEO. HENRY RICHARDS,
Hydrographer.

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List of Stores sent to H.M.S. *Hydra* by Peninsular and Oriental Steamer, October 1867.

Deep-sea hawser-laid line, called No. 1	3,000 fathoms.
Medium „ „ „ 2	5,000 „
Cod „ „ „ 3	8,000 „
Ordinary deep-sea cablet	10,000 „
Cup leads, 28 lbs.	10 in No.
„ 56 „	5 „
„ 112 „	5 „
Brooke's sounding rods, complete	6 „
Iron sinkers for ditto, 112 lbs.	20 „
„ „ 56 „	30 „
„ for ordinary line, 224 lbs.	5 „
Copper swivels, half	96 „
Pins for ditto	60 „
Iron gin blocks	2 „
Reels for sounding lines	26 „
Covers for ditto	26 „

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Hydra's Sounding.

Tuesday, 4th February 1868.

No.	27.	Latitude	17° 46′ 0″ N.
Time	6 a.m.	Longitude	60° 40′ 30″ E.
Wind	Calm.	Barometer	30·23.
Force	0.	Temperature, air	71½°.
Weather	b.c.	„ sea surface	75°.
Sea	smooth.	Depth	2,160 fathoms.
Line	No. 3, with 100 fathoms No. 1.	Bottom	Mud.
Weight	112 lbs.	Surface current	None.
Machine	Brooks.	Value of sounding	Very good.

Fms.	Time.	Interval.	2nd Diff.	From Let go.	Remarks.
	H. M. S.	M. S.	M. S.	H. M. S.	
100	6 43 11	..	..	6 42 29	Gin block about 5 fathoms above water.
200	Missed.				
300	6 45 18	2 7	..	..	
400	6 46 38	1 20	..	..	
500	6 48 6	1 28	0 8	..	
600	6 49 43	1 37	0 9	..	
700	6 51 25	1 42	0 5	..	Line up and down.
800	6 53 16	1 51	0 9	..	
900	6 55 18	2 2	0 11	..	
1,000	6 57 28	2 10	0 8	..	
1,100	6 59 46	2 18	0 8	..	
1,200	7 2 10	2 24	0 6	..	
1,300	7 4 36	2 26	0 2	..	
1,400	7 7 6	2 30	0 4	..	
1,500	7 9 40	2 34	0 4	..	
1,600	7 12 16	2 36	0 2	..	Steaming 2 turns astern.
1,700	7 15 5	2 49	0 13	..	
1,800	7 17 55	2 50	0 1	..	Line slightly out of vertical.
1,900	7 20 45	2 50	0 0	..	
2,000	7 23 39	2 54	0 4	..	
2,100	7 26 42	3 3	0 9	..	
2,200	7 30 33	3 51	0 48	..	
2,300					By feeling line down at 7 h. 29 m. 5 s.
2,400					Sounding by time intervals, 2,140 fathoms.
2,500					Sounding by feeling, 2,170 fathoms.
2,600					
2,700					
2,800					
2,900					
3,000					

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Hydra's Sounding.

Tuesday, 4th February 1868.

No.	28.	Latitude	17° 42′ 0″ N.
Time	5 p.m.	Longitude	59° 50′ 0″ E.
Wind	Calm.	Barometer	30·26.
Force	0.	Temperature, air	76°.
Weather	b.c.	„ sea surface	75°.
Sea	Smooth.	Depth	1,950 fathoms.
Line	No. 3, and 100 fathoms No. 1.	Bottom	Mud.
Weight	168 lbs.	Surface current	None.
Machine	Brooks.	Value of sounding	Very good.

Fms.	Time.	Interval.	2nd Diff.	From Let go.	Remarks.
	H. M. S.	M. S.	M. S.	H. M. S.	
100	5 7 2	..	..	5 6 27	
200	5 7 50	0 50	..	..	
300	Missed.				
400	5 10 0	2 8	..	..	Line up and down.
500	5 11 15	1 15	..	..	
600	5 12 38	1 23	0 8	..	
700	5 14 7	1 29	0 6	..	
800	5 15 43	1 36	0 7	..	
900	5 17 23	1 40	0 4	..	
1,000	5 19 8	1 45	0 5	..	
1,100	5 21 2	1 54	0 9	..	Line checked about 4s.
1,200	5 23 0	1 58	0 4	..	
1,300	5 25 3	2 3	0 5	..	
1,400	5 27 10	2 7	0 4	..	
1,500	5 29 19	2 9	0 2	..	Line up and down.
1,600	5 31 31	2 12	0 3	..	
1,700	5 33 47	2 16	0 4	..	
1,800	5 36 11	2 24	0 8	..	
1,900	5 38 37	2 26	0 2	..	
2,000	5 42 14	3 37	1 11	..	By feeling line down at 5 h. 39 m. 53 s.
2,100					Depth, feeling, 1,947 fathoms.
2,200					Time interval, 1,935 fathoms.
2,300					Thermometer found broken, so no bottom temperature obtained.
2,400					
2,500					
2,600					
2,700					
2,800					
2,900					
3,000					

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Hydra's Sounding.

Wednesday, 5th February 1868.

No.	29.	Latitude	17° 38′ 30″ N.
Time	6 a.m.	Longitude	59° 4′ 0″ E.
Wind	Westerly.	Barometer	30·24.
Force	3.	Temperature, air	74¼°.
Weather	o.c.	,, sea surface	74°.
Sea	Smooth.	Depth	2,000 fathoms.
Line	No. 3, and 100 fathoms No. 1.	Bottom	Mud.
Weight	168 lbs.	Surface current	None.
Machine	Brooks.	Value of sounding	Very good.

Fms.	Time.			Interval.		2nd Diff.		From Let go.			Remarks.
	H.	M.	S.	M.	S.	M.	S.	H.	M.	S.	
100	7	0	56	..		..		7	0	21	Constantly steaming astern to keep the line vertical.
200	7	1	48	0	52	..		..			
300	7	2	49	1	1	0	9	..			
400	7	3	57	1	8	0	7	..			
500	7	5	5	1	8	0	0	..			
600	7	6	33	1	28	0	20	..			
700	7	8	3	1	30	0	2	..			
800	7	9	48	1	45	0	15	..			
900	7	11	33	1	45	0	0	..			
1,000	7	13	23	1	50	0	5	..			
1,100	7	15	24	2	1	0	11	..			
1,200	7	17	28	2	4	0	3	..			
1,300	7	19	27	1	59	0	5	..			
1,400	7	21	35	2	8	0	9	..			
1,500	7	23	44	2	9	0	1	..			
1,600	7	25	57	2	13	0	4	..			
1,700	7	28	21	2	24	0	11	..			
1,800	7	30	35	2	14	0	10	..			
1,900	7	33	8	2	33	0	19	..			
2,000	7	35	34	2	26	0	7	..			
2,050	7	37	40	2	6	..		..			Down at 7 h. 36 m. 6 s., as determined by feeling line, gives 2,015 fathoms.
2,200											By time intervals, 2,000 fathoms.
2,300											
2,400											
2,500											
2,600											
2,700											
2,800											
2,900											
3,000											

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Hydra's Sounding.

Wednesday, 5th February 1868.

No. - 30.
Time - 4 p.m.
Wind - North.
Force - 4.
Weather - b.
Sea - Swell, with short chopping sea from the North.
Line - No. 3, with 100 fathoms No. 1.
Weight - 224 lbs.
Machine - Brooks.

Latitude - - 17° 31′ 30″ N.
Longitude - - 58° 24′ 0″ E.
Barometer - - 30·16.
Temperature, air - 75°.
„ sea surface 74°.
Depth - - - 1,795 fathoms.
Bottom - - - Line broke whilst heaving.
Surface current - None.
Value of sounding - Good.

Fms.	Time.			Interval.		2nd Diff.		From Let go.			Remarks.
	H.	M.	S.	M.	S.	M.	S.	H.	M.	S.	
100	5	11	42	..		..		5	11	7	
200	5	12	30	0	48	..			..		
300	5	13	25	0	55	0	7		..		
400	5	14	25	1	0	0	5		..		
500	5	15	37	1	12	0	12		..		
600	5	16	57	1	20	0	8		..		
700	5	18	14	1	17	0	3		..		
800	5	19	43	1	29	0	12		..		
900	5	21	13	1	30	0	1		..		
1,000	5	22	51	1	38	0	8		..		
1,100	5	24	30	1	39	0	1		..		
1,200	5	26	27	1	57	0	18		..		
1,300	5	28	23	1	56	0	1		..		
1,400	5	30	26	2	3	0	7		..		
1,500	5	32	30	2	4	0	1		..		
1,600	5	34	39	2	9	0	5		..		
1,700	5	36	51	2	12	0	3		..		
1,800	5	39	4	2	13	0	1		..		
1,850	5	41	24	2	20	..			..		By feeling down at 5 h. 39 m. 4 s. Time intervals give the same depth, 1,795 fathoms.
2,000											
2,100											
2,200											
2,300											
2,400											
2,500											
2,600											
2,700											
2,800											
2,900											
3,000											

Steaming astern to keep line vertical, as requisite.

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Hydra's Sounding.

Thursday, 6th February 1868.

No. - 32.
Time - 4 p.m.
Wind - N. by E.
Force - 3–4.
Weather - b.
Sea - Slight swell, with short sea from the North.
Line - No. 2, with 100 fathoms No. 1.
Weight - 224 lbs.
Machine - Brooks.

Latitude - - 17° 11′ 30″ N.
Longitude - - 56° 56′ 0″ E.
Barometer - - 30·22.
Temperature, air - 73½°.
,, sea surface 74°.
Depth - - - 1,940 fathoms.
Bottom - - - Mud.
Surface current - None.
Value of sounding - Very good.

Fms.	Time.	Intervals.	2nd Diff.	From Let go.	Remarks.
	H. M. S.	M. S.	M. S.	H. M. S.	
100	5 22 50	..	..	5 22 25	Gin block 5 fathoms above water.
200	5 23 48	0 58	..	..	
300	5 24 48	1 0	0 2	..	
400	5 25 51	1 3	0 3	..	
500	5 27 1	1 10	0 7	..	
600	5 28 15	1 14	0 4	..	
700	5 29 37	1 22	0 8	..	
800	5 31 7	1 30	0 8	..	
900	5 32 58	1 51	0 21	..	Line checked for 11 s.
1,000	5 34 38	1 40	0 11	..	
1,100	5 37 19	2 41	1 1	..	Line held on for 1 m. between 11 and 12; line 10 fathoms too long.
1,200	5 39 21	2 2	0 39	..	
1,300	5 41 24	2 3	0 1	..	
1,400	5 43 25	2 1	0 2	..	
1,500	5 45 40	2 15	0 14	..	
1,600	5 48 8	2 28	0 13	..	
1,700	5 50 28	2 20	0 8	..	
1,800	5 53 2	2 34	0 14	..	
1,900	5 55 39	2 37	0 3	..	
1,950	5 57 18	1 29	..	..	
2,000	5 59 7	1 59	..	..	By feeling line down at 5 h. 56 m. 27 s. gives 1,930 fathoms.
2,100	Excess between 11 and 1,200 -			+ 10 fms.	+ 5
2,200	Height gin block -			— 5	1,935 fms.
2,300	Gives correction -			+ 5 fms.	
2,400					Time interval gives 1,934
2,500					+ 5
2,600					1,939 fms.
2,700					
2,800					
2,900					
3,000					

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Hydra's Sounding.

Friday, 7th February 1868.

No. - 33.
Time - 6 a.m.
Wind - Easterly.
Force - 1.
Weather - b.c.
Sea - Smooth.
Line - No. 2, with 100 fathoms
No. 1.
Weight - 168 lbs.
Machine - Brooks.

Latitude - - 17° 13′ 0″ N.
Longitude - - 56° 17′ 0″ E.
Barometer - - 30·23.
Temperature, air - 72°.
„ sea surface 74¾°.
Depth - - - 1,670 fathoms.
Bottom - - - Mud.
Surface current - None.
Value of sounding - Very good.

Fms.	Time. H.	M.	S.	Interval. M.	S.	2nd Diff. M.	S.	From Let go. H.	M.	S.	Remarks.
								7	8	20	
100	7	8	56	..		..					
200	7	10	5	1	9	..			..		
300	7	11	11	1	6	0	3		..		
400	7	12	27	1	16	0	10		..		Steaming astern.
500	7	13	57	1	30	0	14		..		Steaming astern.
600	7	15	32	1	35	0	5		..		
700	7	17	9	1	37	0	2		..		
800	7	19	3	1	54	0	17		..		Steaming astern.
900	7	20	55	1	52	0	2		..		
1,000	7	22	54	1	59	0	7		..		
1,100	7	25	7	2	13	0	14		..		Steaming astern.
1,200	7	27	27	2	20	0	7		..		
1,300	7	29	46	2	19	0	1		..		
1,400	7	32	5	2	19	0	0		..		
1,500	7	34	23	2	18	0	1		..		
1,600	7	36	45	2	22	0	4		..		
1,700	7	39	37	2	52	..			..		By feeling, down at 7 h. 38 m. 48 s. gives 1,686 fms. + 5 = 1,691 fms.
1,800											
1,900											
2,000											
2,100											By intervals, depth 1,663 + 5 = 1,668 fms.
2,200											
2,300											
2,400											Temperature of the bottom, 36½° F.
2,500											
2,600											
2,700											
2,800											
2,900											
3,000											

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HYDRA'S SOUNDING.

Monday, 29th June 1868.

No. - Atlantic 1.
Time - 10h. 30m. a.m.
Wind - S.E.
Force - 2.
Weather - c.
Sea - Smooth, swell from S.W.
Line - No. 2, with 100 fathoms / No. 1.
Weight - 272 lbs.
Machine - Gibbs, with tube.

Latitude - - 31° 3′ 24″ S.
Longitude - - 12° 50′ 45″ E.
Barometer - - 30·26.
Temperature, air - 59°.
„ sea surface 61°.
„ density - 27°.
Depth - - - 1,880 fathoms.
Bottom - - - White mud and minute shells.
Surface current - None.
Value of sounding - Very good.

Fms.	Time. H.	M.	S.	Interval. M.	S.	2nd Diff. M.	S.	From Let go. H.	M.	S.	REMARKS.
100	9	47	22	..		..		9	46	53	Vessel going astern against the wind, as requisite, to keep the line vertical.
200	9	48	19	0	56	..			..		
300	9	49	22	1	4	0	8		..		
400	9	50	31	1	9	0	5		..		
500	9	51	46	1	15	0	6		..		
600	9	53	4	1	18	0	3		..		
700	9	54	27	1	23	0	5		..		
800	9	55	53	1	26	0	3		..		
900	9	57	25	1	32	0	6		..		
1,000	9	59	0	1	35	0	3		..		Checked line to bend.
1,100	10	0	41	1	41	0	6		..		
1,200	10	2	22	1	41	0	0		..		
1,300	10	4	3	1	41	0	0		..		
1,400	10	5	52	1	49	0	8		..		
1,500	10	7	41	1	49	0	0		..		
1,600	10	9	35	1	54	0	5		..		
1,700	10	11	31	1	56	0	2		..		
1,800	10	13	30	1	59	0	3		..		
1,900	10	15	27	1	57	0	2		..		
1,950	10	17	15	1	48	..			..		
2,000	10	19	19	2	4	..			..		By accumulator strain line vertical depth 1,880 fathoms. By time intervals, depth 1,908 fathoms. — 5 = 1,903
2,100											
2,200											
2,300											
2,400											
2,500											
2,600											Temperature of bottom, 37½° F.
2,700											Density of water brought up (tem. 61) = 25¾°.
2,800											
2,900											
3,000											

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Hydra's Sounding.

Tuesday, 30th June 1868.

No. - Atlantic 2.
Time - 2 p.m.
Wind - Variable.
Force - 1.
Weather - b.c.m.
Sea - Smooth.
Line - No. 2 line, 100 fathoms; No. 1.
Weight - 400 lbs.
Machine - Gibbs, with tube.

Latitude - - 29° 35′ 54″ S.
Longitude - - 10° 42′ 15″ E.
Barometer - - 30·22.
Teperature, air - 63° F.
„ density - 27°.
„ sea surface 61°.
Depth - - - 2,330 fathoms.
Bottom - - - White mud, with minute shells.
Surface current None.
Value of sounding - Very good.

Fms.	Time. H.	M.	S.	Interval. M.	S.	2nd Diff. M.	S.	From Let go. H.	M.	S.	Remarks.
100	1	26	22·5	..		..		..			
200	1	27	12	0	49·5	..		..			
300	1	28	3·5	0	51·5	0	2	..			
400	1	28	58	0	54·5	0	3	..			
500	1	29	57·5	0	59·5	0	5	..			
600	1	31	1	1	3·5	0	4	..			
700	1	32	10	1	9	0	5·5	..			
800	1	33	24	1	14	0	5	..			
900	1	34	42	1	18	0	4	..			
1,000	1	36	5	1	23	0	5	..			
1,100	1	37	45	1	40	0	17	..			A strain on line to bend.
1,200	Mark missed.										
1,300	1	40	30·5	2	45·5	..		..			
1,400	1	41	59·5	1	29	..		..			
1,500	1	43	31·5	1	32	0	3	..			
1,600	1	45	6	1	34·5	0	2·5	..			
1,700	1	46	43·5	1	37·5	0	3	..			
1,800	1	48	24	1	40·5	0	3	..			
1,900	1	50	5	1	41	0	0·5	..			
2,000	1	52	4	1	59	0	18	..			
2,100	1	54	14	2	10	0	11	..			A strain on line to bend.
2,200	1	55	53·5	1	39·5	0	30·5	..			
2,300	1	57	40	1	46·5	0	7	..			
2,400	2	0	11	2	31	0	44·5	..			By intervals, line out, 2,360
2,450	2	2	7	1	56	..		..			— 5
2,600											Depth by in. 2,355
2,700											By accumulator, depth 2,330 fms.
2,800											
2,900											
3,000											

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HYDRA'S SOUNDING.

Saturday, 4th July 1868.

No. - Atlantic 4.
Time - 2 p.m.
Wind - S.W.
Force - 3.
Weather - b.c.
Sea - Smooth, swell from S.W.
Line - No. 2, with 100 fathoms No. 1.
Weight - 368 lbs.
Machine - Gibbs, with tube.

Latitude - - 22° 58′ 0″ S.
Longitude - - 2° 43′ 45″ E.
Barometer - - 30·25.
Temperature, air - 66°.
„ density - 26°.
„ sea surface 65½°.
Depth - - - 2,600 fathoms.
Bottom - - - Pale grey mud, with minute shells.
Surface current - No current.
Value of sounding - Very good.

Fms.	Time. H.	M.	S.	Interval. M.	S.	2nd Diff. M.	S.	From Let go. H.	M.	S.	REMARKS.
100	1	17	50	..		..		..			Line kept vertical by vessel going astern against the wind.
200	1	18	44	0	54	..		..			
300	1	19	43	0	59	0	5	..			
400	1	20	44	1	1	0	2	..			
500	1	21	50	1	6	0	5	..			
600	1	23	2	1	12	0	6	..			
700	1	24	20	1	18	0	6	..			
800	1	25	40	1	20	0	2	..			
900	1	27	1	1	21	0	1	..			
1,000	1	28	25	1	24	0	3	..			
1,100	1	30	4	1	39	0	15	..			Strain kept on line to bend.
1,200	1	31	33	1	29	0	10	..			
1,300	1	33	0	1	27	0	2	..			Reel broke lowering line by hand.
1,400	1	35	36	2	36	..		..			
1,500	1	37	34	1	58	..		..			
1,600	1	39	20	1	46	..		..			
1,700	1	41	28	2	8	..		..			
1,800	1	43	45	2	17	..		..			
1,900	1	45	50	2	5	..		..			
2,000	1	48	10	2	20	..		..			Held on line to bend and clear line, 8 minutes running from new reel, let go No. 1 line at 1h. 59m. 8s.
2,100	1	51	12	3	2	..		..			
2,200	2	0	57	1	49	..		..			
2,300	2	2	51	1	54	0	5	..			Sounding by intervals, 2,576
2,400	2	4	46	1	55	0	1	..			
2,500	2	6	43	1	57	0	2	..			— 5
2,600	2	9	1	2	18	0	25	..			2,571 fathoms.
2,650	2	10	54	1	53	..		..			2,580 by accumulator
2,800											+ 20 by correction tube, between 2,100 and 2,200 fms.
2,900											Corrected depth, 2,600 fathoms.
3,000											

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HYDRA'S SOUNDING.

Monday, 6th July 1868.

No.	Atlantic 5.	Latitude	19° 22′ 30″ S.
Time	2 p.m.	Longitude	1° 44′ 0″ W.
Wind	S.S.E.	Barometer	30·36.
Force	5 to 7, squally.	Temperature, air	69°.
Weather	b.c.	„ density	26°.
Sea	High cross sea.	„ sea surface	68°.
Line	No. 2, and 200 fathoms No. 1.	Depth	2,830 fathoms.
Weight	378 lbs.	Bottom	Soft brown mud, with minute shells.
Machine	Gibbs, with tube.	Surface current	None.
		Value of sounding	Very good.

Fms.	Time.	Interval.	2nd Diff.	From Let go.	Remarks.
	H. M. S.	M. S.	M. S.	H. M. S.	
100	12 44 32	..	..	..	Vessel's engines going astern to keep line vertical throughout.
200	12 45 30	0 58	..	..	
300	12 46 24	0 54	0 4	..	
400	12 47 27	1 3	0 9	..	
500	12 48 39	1 12	0 9	..	
600	12 49 50	1 11	0 1	..	
700	12 51 3	1 13	0 2	..	
800	12 52 22	1 19	0 6	..	
900	12 53 46	1 24	0 5	..	
1,000	12 55 17	1 31	0 7	..	
1,100	12 56 52	1 35	0 4	..	
1,200	12 58 58	2 6	0 31	..	Strain on line to bend.
1,300	1 0 34	1 36	0 30	..	
1,400	1 2 14	1 40	0 4	..	
1,500	1 3 56	1 42	0 2	..	
1,600	1 5 43	1 47	0 5	..	
1,700	1 7 38	1 55	0 8	..	
1,800	1 9 31	1 53	0 2	..	
1,900	1 11 31	2 0	0 7	..	
2,000	1 13 28	1 57	0 3	..	
2,100	1 15 46	2 18	0 21	..	Strain kept on line to bend.
2,200	1 17 55	2 9	0 9	..	
2,300	1 19 57	2 2	0 7	..	
2,400	1 21 58	2 1	0 1	..	Depth by intervals, 2,837 − 5 = 2,832 fms.
2,500	1 24 3	2 5	0 4	..	
2,600	1 26 8	2 5	0 0	..	
2,700	1 28 17	2 9	0 4	..	
2,800	1 30 34	2 17	0 8	..	
2,900	1 33 33	2 59	0 42	..	
2,950	1 35 18	1 45	..	..	

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